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ACID BLAST PROCESS FOR ETCHING.*

BY LOUIS EDWARD LEVY,
Member of the Institute.

The present device, which may be termed an Acid Blast, while primarily intended to facilitate the etching of photo-chemical printing plates is also applicable in all cases where the chemical erosion of metals or of glass is to be effected. The invention consists essentially in the application of a powerful blast of atomized acid or other erodent in place of the customary immersion bath. Along with the means of producing the requisite blast of comminuted acid and of applying it for the purpose in view, there is combined an arrangement for the necessary washing of the

* Abstract of a paper on a new method of etching, read in connection with a demonstration of the invention, at the stated meeting of the Institute, February 15, 1899.

plate, which affords an increased convenience of procedure and a consequent saving of time in the course of the work.

Preliminary to a description of the blast method of etching a cursory review of the customary immersion process may be desirable. The preparation of the design for the etching process being the same for the blast as for the immersion method, the details of that procedure need not be dwelt upon. The erodent must, of course, be adapted to the work required, and be in fluid form; thus, for the etching of a zinc plate a solution of nitric acid may be regarded as preferable; for copper, a solution of iron chloride; for glass, its well-known solvent, hydrofluoric acid, etc.

Assuming the plate to be of zinc and the design as having been produced on it in some fatty ink by the usual photographic process, the plate is prepared for the etching process by first melting into combination with the inked image some resinous powder to strengthen it against the action of the acid, and then protecting the back of the plate by smearing it, while still warm from the first melting, with a covering of shellac or asphaltum varnish.

The plate having cooled, is now immersed, face upward, in a flat bath of dilute nitric acid. The acid enters into combination with the exposed metal, and the surface of the plate is immediately covered with a layer of minute bubbles of hydrogen gas, which, if the action proceeds undisturbed, gradually combine into larger bubbles that finally rise to the surface. Coincident with the development of the gas bubbles there is formed a deposit of zinc nitrate, which adheres to the plate as a dark scum, except where it is lifted from the surface by the larger bubbles as they arise. The bubbles and the deposit would, if left on the plate, retard the action of the acid and cause it to proceed unevenly, and to avoid this the etcher, with a suitable brush, removes these obstructions from the plate.

It is plain that the acid tends to combine with all of the metallic surface that is exposed. Accordingly, as soon as the plate is immersed in the bath, the etching proceeds not only downwards, but sidewards into the plate as well. The resistant which forms the design protects the surface of the

underlying metal from the corrosion of the acid, but if the lines or stipples of the design be thin, say an hundredth of an inch wide, the acid, eating its way on both sides of the lines, will cut sidewards through the one-hundredth of an inch thickness by the time it has etched downwards one-half as much. Consequently where thin lines or stipples have to be retained in the plate, as in the case of fine line or stipple drawings, the etching must be halted at a very shallow depth, and the sides of the lines protected from the action of the acid.

This is done by covering the exposed sides of the lines with some resinous powder carried over the plate at an angle to its surface by means of a camel's-hair brush. This operation requires a trained and skillful hand; when the powder is properly distributed, the plate is heated, the powder melted in place, and the plate then cooled. This procedure is repeated, the powder being brushed successively in four opposite directions across the plate, and when completed, the latter is ready for the so-called "second etch."

The depth to which this second etching can be safely carried depends largely on the extent to which the resinous powder has been deposited by the etcher against the base of the lines, which is varied by the operator according to the character of the work itself. The etching is permitted to proceed downwards until the lines or stipples begin to be jeopardized by the sideward action of the acid. This condition results the sooner by reason of the fact that the acid covering the plate is forced over it horizontally to and fro by a rocking motion given to the trough containing the bath, a proceeding which is requisite not only to expedite the work, but also to diffuse the heat generated by the erosion. Meanwhile, the brush has to be applied assiduously over the plate, to remove the bubbles and the deposit as they develop. When the sides of the lines have become bared to the point of danger, the work is again halted and the four-way powdering operation is repeated to prepare the plate for the "third etch." This usually suffices to enable the etching to proceed to a point beyond which any further deepening required is left to the router, but for specially fine work the

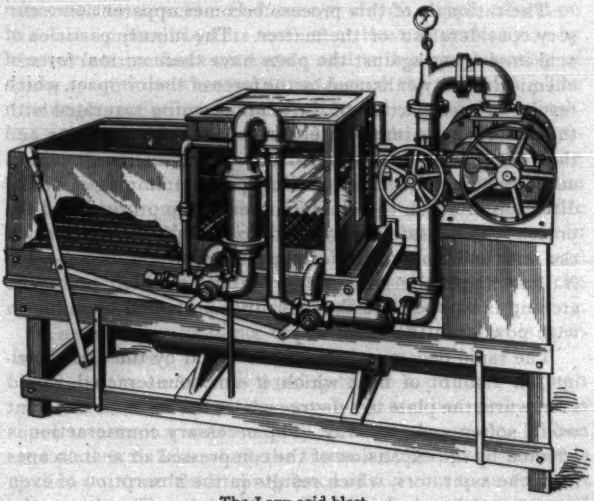
etching is not allowed to proceed so far, and the covering of the lines is repeated for a fourth or fifth time.

After the third powdering, which usually covers all the closer depressions of the etching completely, a stronger solution of the etching liquid can be used, the etcher regulating the work with his brush, the tray being meanwhile rocked, either mechanically or by the etcher himself, to further the even action of the acid.

The process of etching a zinc line plate usually takes from one and one-half to two and one-half hours, according to the depth of the etching required, which varies with the character of the work itself. Newspaper illustrations are frequently etched to a practicable depth in an hour's time, but often at the expense of the quality of the result. The strong acid solution required in such a procedure is apt to cut through the thin protection of the edges of the lines, and leave them serrated, or, as it is technically called, "rotten." Coincidently the rapid combination of the acid with the metal heats the plate and the liquid, which necessitates the addition of ice to keep down the temperature and prevent the etching ground from giving way through softening, and which furthermore gives rise to fumes that are very deleterious to the etcher, few operators being able to continue at such work permanently.

With the etching blast the time required to complete an etching is materially shortened and the etcher is freed from the necessity of breathing in the gaseous products of the etching process. At the same time, the technical qualities of the result are secured in a degree obtained only by the best hand-etching, both as regards the delicacy of the lines left in relief and the depth of the etching between the closest lines or stipples of the design. The plate, prepared as has already been noted, in the usual manner, is clamped against a carrier board, face upward, and the back of the plate, being fixed closely against the surface of this board, is thus protected from the action of the blast of acid, and therefore needs no covering of protecting varnish, nor the removal of such covering after the etching is finished, as is the case with the immersion method. The board carrying

the plate is now placed, with the design face downward, in an open frame which is slid into another movable frame within the etching box. This inner frame, carrying the sliding frame with the board and plate, is connected by a rod to an excentric worked from the driving shaft of the compressor. The motion of this shaft, thus imparted to the inner frame, gives the latter, with its contained carrier and plate, a reciprocal movement through a space equal to the distance between the nozzles of the aspirators below.



The Levy acid blast.

The etching box, preferably made with glass sides, is open at the bottom and is placed in a tray or tank containing a solution of the acid. Under the surface of the liquid are a series of tubes connected with an air compressor and provided with a large number of atomizing nozzles which protrude above the surface of the liquid. When the air compressor is set in motion and the air current directed into the tubes and out of the protruding nozzles, the acid is sucked in through openings in the bottoms of the aspirators and

projected upwards in the form of an atomized spray against the surface of the plate. The aspirators are so arranged that the spray, at the point of its contact with the plate, is a homogeneous body of acid vapor moving towards the plate at a right angle to its surface and with a velocity which causes it to impinge on the plate with a forcible impact. The result is a very rapid etching of the plate by the acid, and the procedure of this etching to a very considerable depth without any undercutting.

The rationale of this process becomes apparent on a cursory consideration of the matter. The minute particles of acid impinging against the plate have their normal force of chemical affinity enhanced by the force of their impact, which results in each particle of the acid becoming saturated with the metallic base immediately on contact with the latter, and thus losing the power of further dissolving the metal in any direction. Each succeeding particle impinges in the direction in which the etching is desired to proceed, and the process can be safely continued to a depth beyond which the finer and closer lines of the design would become too frail to stand the strain of printing, at which point the etching is stopped and the finer lines protected by filling in with powder in the usual way.

The rapid decomposition of the metal by the acid develops an amount of heat which, if not counteracted, would soon warm the plate to a degree where the resinous resistant would soften and give way. The necessary counteraction is effected by the expansion of the compressed air as it escapes from the aspirators, which results in the absorption of even more heat than is developed on the plate. This keeps the plate and the etching liquid quite cool, even in warm weather, and consequently avoids the necessity of applying ice for the purpose.

The bubbles of hydrogen and the metallic scum which form on the plate in the course of the chemical process, are cleared off by the force of the blast as fast as they develop, and thus the necessity of the operator standing over the work to remove these obstructions is avoided.

The gases and vapor fumes, which are so abundantly

generated in a rapid chemical decomposition, are carried off by the escaping air current through a ventilating chimney from the interior of the etching-box. The work-room is thus kept free from these deleterious vapors, and the health of the operator is secured against their effects.

The etching liquid carried by the blast may, of course, be varied for different requirements. In etching copper by means of iron chloride the gain of efficiency, as compared with the immersion method, is as marked as in etching zinc with nitric acid. Half-tone or crayon stipple effects on zinc are rendered by this method at least as perfectly as by the current methods on copper, and with a great saving of time, apart from the saving in cost of the material. The thorough rendering of half-tone reproductions in zinc etchings by the immersion method, though quite feasible, requires intelligent and skillful handling, the work being much less automatic than in the etching of copper half-tone effects with iron chloride. With a blast of atomized dilute nitric acid a half-tone etching on zinc can be produced in two minutes, with a purity of the edges of the lines and stipples fully equal to that obtainable on copper with the immersion bath, and with a far greater depth of the etching.

The washing appliance connected with the blast is operated as follows:

While the air blast is passing to the aspirators through pipes connected by a three-way cock, another such cock is open to permit a water supply to enter a reservoir. When the plate is to be washed, the frame with the plate carrier is pulled out from the etching box and slid over to an adjacent compartment, at the bottom of which are fixed a series of perforated pipes. A thrust of a lever connecting the two three-way cocks turns the air current from the direction of the aspirators through another pipe to the top of the water reservoir, at the same time turning off the supply from the latter and opening a way for the water from the reservoir to the perforated pipes beneath the plate. The air pressure forces out the water in a sharp jet against the plate and washes its entire surface clean in a few seconds.

The etching and the washing compartments occupy each

a half of a single tank, divided in the middle by a partition. Passing through this partition at the bottom, under the level of the latter, is a movable L-shaped tube, which, when the outer arm is in vertical position, determines the level of the liquid in the etching compartment. A small quantity of the liquid being carried off with each plate and washed away by the water-jet, this loss is made good by a replenishment of fresh and slightly stronger acid solution, which suffices in practice to keep the etching liquid up to its normal strength and quantity.

A considerable saving of the acid or other etching liquids is thus effected, there being here no occasion for the constant renewal and wastage of the acid, which is inevitable in the current practice.

When the etching liquid is to be removed, the vertical arm of the connecting L is turned down to a horizontal position, which permits the liquid to drain into the washing compartment and thence out through the waste pipe of the latter.

The acid blast and the mechanism for its application have been patented in this country and abroad.

ELECTRICAL SECTION.

"Railroad" Meeting, March 28, 1899.

SOME OF THE LARGER TRANSPORTATION PROBLEMS IN CITIES.

BY EDWARD E. HIGGINS.

[*Concluded from p. 327.*]

THE PROBLEM OF CARS AND CAR SERVICE.

Upon the character of the cars and the car service of a street railroad depends largely the gross revenue which will be derived from the public. One of the keynotes to success in handling street railway property is to bring about to the greatest possible extent "short-distance riding." The

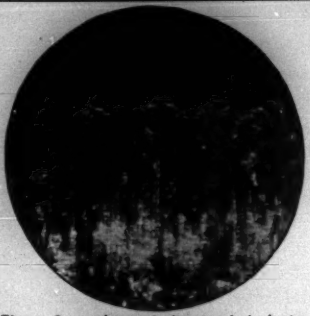


Fig. 1.—Immersion method, one etch, 4 minutes.

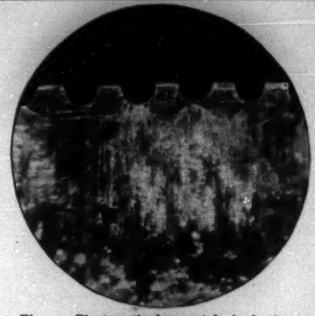


Fig. 2.—Blast method, one etch, 4 minutes.

Fig. 3.—Immersion method, two etches; first etch 4 minutes, then powdered against right wall of depression, then second etch of 6 minutes.

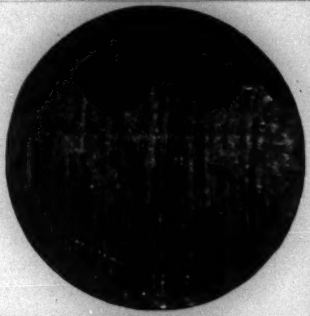


Fig. 4.—Blast method, one etch, 4 minutes.

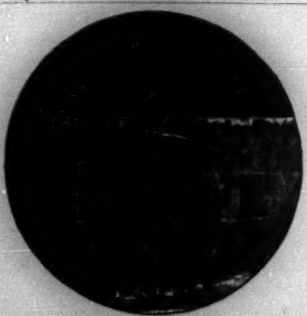


Fig. 5.—Immersion method, isolated line, one etch, 8 minutes.

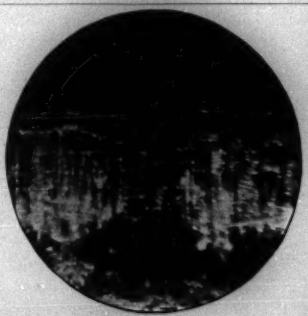


Fig. 6.—Blast method; isolated line, one etch, 4 minutes.

LEVYTYPE CO., ENGRAVERS AND PRINTERS, PHILADELPHIA.

Sections of Zinc Plates, magnified 24 diameters, showing comparative effects of etching by Immersion and by Blast Process. Reagent, Nitric acid, 10° Beaumé.

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number of times that a car can load up and empty itself upon a trip governs the success of that car from a profit-earning standpoint. For this reason it is essential that cars be run frequently enough to make them a convenience to those who would walk were not the opportunity of riding offered on the instant. But on the other hand, the frequency is limited by the number of people who could by any possibility be induced to ride. In practice the manager has to experiment with car frequency until he strikes that which will bring about maximum earnings, and at this point it is not far from the truth to say that the public is well served.

The car service must also be rapid, for the short-distance rider takes a car not only because it is right at hand, but also because he can save some minutes in getting to his destination.

The car must be comfortable and well lighted, by windows in the day and by lamps at night, for the further advantage and attraction of the traveling public. Never has there been such attention given to the comfort and convenience of the people as in these days of electric traction. When the investments are large, the business required to maintain that investment must also be large, and the margin between success and failure is so small that an inferior or unpopular service means a loss of business sufficient to turn the scale. In some of the Western cities, St. Louis in particular, where several companies are competing for business in the same territory, there have been developed many novel and attractive types of cars, to the advantage of the public if not the companies. The carrying of traffic is so delicately adjusted in cities like St. Louis that oftentimes the appearance of ten or fifteen new and beautiful cars on a given line has meant an increase in receipts on that line of hundreds of dollars a day, and a corresponding diminution on the lines paralleling it. These other lines finding it necessary, of course, to get back their traffic, have been forced to order even better and more attractive cars. In the old horse-railway days, 12-foot, 14-foot, and 16-foot closed cars with longitudinal seats, and 6- or 7-bench open cars

with cross seats were in almost universal use, though many railways denied themselves and the public the luxury of the open cars. To-day cars range in length from 20 to 40 feet, and a 16-foot car looks almost as small and as much out of place as the old 10-foot and 12-foot cars of the horse railway era. With these longer cars has come greater steadiness in riding, and trucks have been greatly improved to the end of bringing this about. The West, always in advance of the East in obtaining beauty and convenience in railroad passenger trains, is somewhat in advance of the East also in street railway cars, and in St. Louis, Milwaukee, Denver, San Francisco and elsewhere, will be found some of the most beautiful travel-attracting street cars in the world, with cross seats, center aisles, broad windows, window-guards, electric signals, and elegant fittings throughout.

Somewhat strangely perhaps, the almost universal foreign custom of providing roof seats on tramway cars has not been popular in this country, the reason appearing to be that such cars are better adapted for slow speeds than for high, and for countries whose peoples do not place upon time the same value that Americans do, for there is no question that it would be impossible to keep up the present schedule speeds on American street railroads if the cars were obliged to take time to load and unload passengers to and from the roof seats, while the danger of accident to people not used to climbing up and down the stairs while cars are in rapid motion would be considerable.

The manager or employé who lays out the schedules of a street railway has in his hand when doing this work the operating profits of the enterprise. If he is too niggardly with car mileage, he saves a little in expenses, but may perhaps reduce gross income by a far greater sum than the savings. If, on the contrary, he is extravagant with car mileage, he may increase expenses far more than income. The mean is, indeed, a golden one and worth a never-ending series of experiments to determine the maximum traffic and profit that can possibly be derived from any given line. In more than one instance, a languishing or unprofitable enterprise has been turned into a vigorous and profitable

one by the mere application of common-sense principles to the car service.

THE PROBLEM OF TRACK AND ROADBED.

The introduction of longer and heavier cars, a much more frequent service and a self-propelling power which needs to obtain a grip on the rails, have enormously increased the difficulties of the track problem for street railway companies, and on all sides are being heard complaints that joints are wearing out, rails are showing excessive wear in spots, leading to unevenness of track, and that the repairs and depreciation of roadbed for electric traction have been underestimated. The most heavily worked track and special work of the larger cities will stand hardly three years of service, and the life of electric track varies from this period to ten or twelve years as a maximum, according to our present experience. When it is stated that it costs from $10,000 to $25,000 a mile to replace track, it can easily be seen how serious is this problem, and how great a burden upon the finances of a company is the track repair and depreciation account. In the few places where street railway profits seem excessive, therefore, such burdens as these, which are yet, in all their seriousness, of the immediate future rather than of the present, should be remembered.

THE PROBLEM OF FARES.

In this country a uniform 5-cent fare is almost universal; in other countries a variable fare, based on distance traveled, is equally universal. There is something more than a mere financial policy involved in the discussion of the fare problem. Broadly speaking, a uniform fare means depopulation of the tenement-house districts and settlement of the suburbs—means a clear happy life in purer air and better surroundings—means individual homes and plenty of room for the children. A graded fare means enormous density of population in the heart of the city, scanty suburban settlements, pale faces, sickly children and a miserable home-life for the masses. These words are not too strong, nor is the influence of street railway fares upon these

living conditions exaggerated. The difference between the street railway track mileage and investment in our principal cities and those of equal size abroad is something amazing. Compare, for example, Brooklyn, Glasgow and Boston, three cities of about the same size. Brooklyn with a population of about 900,000, within 5-cent fare limits, has over 500 miles of track; Boston, with 700,000 population, has 325 miles of track, while Glasgow, with 800,000 population has but 77 miles of track. The total street railway investment in Brooklyn is nearly $100,000,000, in Boston is over $25,000,000, and in Glasgow less than $4,000,000. The 800,000 people of Glasgow are distributed over but 23 square miles, Brooklyn's 900,000 inhabitants live in a 45-mile area, and have a population density of but 25,000 per square mile, while Boston's 700,000 inhabitants are happy in 122 square miles of area, with a population density of but 5,700 per square mile. Is not the uniform fare principle justified by these figures alone?

For 5 cents a citizen of Brooklyn may travel more than 10 miles. A citizen of any of our great cities can travel 10, 15 or even 20 miles. In doing so he inflicts a loss upon the company, and if there were a large proportion of the total number of passengers carried who traveled so far, or even 5 or 10 mile distances, our city railway properties would be continually unprofitable and probably insolvent. It is in the short distance riding that the losses are made up, and it must, therefore, in frankness be admitted that the short distance rider pays part of the fare of him who rides the longer distance. This is an apparent injustice, which cannot, however, be remedied unless the whole principle and policy of American street railroading be radically changed, and the effect of the change would be undoubtedly disastrous from a sociological point of view, tending to check the expansion of cities into the suburbs and increase the congestion of life in the centers.

Is the present 5-cent fare too high, and can it be reduced without consequent disasters to street railway companies? Both these questions can be most emphatically answered in the negative. The street railway companies of

to-day are giving to their patrons a maximum ride two or three times greater than that given for the same price ten years ago, and an average ride at least 50 per cent. greater; they are giving them a speed in transit from 50 to 100 per cent. greater; and are providing them with cars, cleaner, finer, better lighted, and in all respects superior to the old régime. Is a mere change of motive-power from horses to electricity a magical thing that can multiply wealth as by a philosopher's stone and make all things possible? No. The street railway companies of the country are by no means unduly prosperous to-day. In fact, too many of them are struggling under far heavier burdens than ever ought to have been put upon them by the people. In Philadelphia, for example, the right to change the motive-power from horses to electricity has been granted on condition that the street railway company shall lay down new pavement and permanently maintain this pavement on over 400 miles of street within the city limits—a condition more enormous perhaps than that ever before laid upon a quasi-public industry, and one which will make the payment of excessive dividends or a reduction of fares impossible for many years to come, if not forever. Take twenty of the great street railway properties of the country, none earning less than $1,000,000 gross per annum. Their aggregate capitalization in bonds and stock outstanding is nearly $500,000,000; their aggregate gross receipts are about $67,000,000; their apparent operating expenses (including taxes) are about $42,000,000, or 63 per cent. of the gross receipts; and the percentage of apparent earnings from operation amount to barely 5 per cent. on the total capitalization.

"But these properties are overcapitalized," it will be said.

Admitted.

Suppose I assume, too, for the sake of the argument, that the overcapitalization is 100 per cent., that the real accumulated cash investment in all these particular properties is not $500,000,000, but $250,000,000. This certainly would seem to be an assumption sufficiently sweeping to suit any critics, and is far larger than the fact.

As a result, we have apparent net earnings equivalent to a return upon investment of 10 instead of 5 per cent. Is this larger figure too great for risks so serious as those which have to be taken by investors in street railway properties?

But this is not all. These twenty properties are not now in reality earning 5 per cent. on their $500,000,000 of their capital liabilities, or 10 per cent. on half this amount. They are knowingly or unknowingly deceiving themselves in the matter of maintenance, and some day there will be a reckoning in consequence. In other words, their percentage of operating expenses to gross receipts is much more than 63 per cent., and perhaps hardly less than 75 per cent., and they are probably earning on an average but 4 per cent. or less on their capitalization.

THE PROBLEM OF TRANSFERS.

To most people, no doubt, the transfer problem appears a very simple one. Surely it would seem that no more just and reasonable demand could be made on a street railway management than that a passenger should be allowed to ride from any point within a city to any other for a single fare, particularly if the entire system is owned by one company and if the city is a small one. It is on deeper investigation only that the real difficulties appear. Broadly speaking, it may be said quite certainly that hardly a street railway manager in the country would object to the simple proposition outlined above if that were all there were to the problem. It is not of serious importance to him whether a passenger complete his ride on the original car or on a connecting one. The trouble is found in limiting the use of transfers to their entirely legitimate purpose without running against sheer dishonesty on the part of the public and on that of the company's own employés. The entire transfer problem is one of preventing this dishonesty and of nothing else. To prevent conductors from replacing cash fares with transfers is possible only by the most careful comparison of returns and records in connection with a more or less complete detective force, and the cost of this

combined service is often very large. But a more serious trouble than this by far is found in the "swapping" of transfers by, for example, clerks in the same offices living in different parts of the city, or by their improper use in other ways for return or continuation trips, and in the actual giving away or selling of transfers taken for that purpose at the close of the honest trip. There are not a few cities in which the routes are so peculiarly laid out as to make it practically impossible to put into effect a transfer system which cannot be thus tampered with to a most serious extent, while in all cities there is a more or less large percentage loss from illegitimate use. The fact that in nearly all cities of America the street railroad companies have conceded some form of transfer accommodation, and are standing the consequent loss in receipts and in operating expenses, should be credited to them as a partial offset for some of the things which they have been obliged to refuse the public.

THE AVOIDANCE OF ACCIDENTS.

In the operation of many cars through crowded streets of cities, it is inevitable that there should be accidents, trivial and serious, from the running down of a peddler's cart to the killing and maiming of a carload of passengers. The fact that the trivial accidents are so few and the serious ones so extremely rare in proportion to the number of passengers carried, and to the number of obstructions, human and otherwise, in the streets, points to the remarkable care which is uniformly exercised by the employés of our great companies working under carefully established rules. During the year ending September 30, 1897, the street railway cars of the entire State of Massachusetts ran 61,577,917 miles, and carried 308,684,224 passengers. The number of accidents of all kinds was so extremely small that the cars traveled on an average over 48,000 miles before injuring a passenger, and about 83,000 miles before injuring any one in the streets or highways through which they passed. The number of fatal injuries was only one for each 200,000 miles traveled. The number of fatal injuries to passengers was but

one for each 30,000,000 carried. This is a marvelous record considering the character of the "rights of way" which street railways possess, and indicates the most careful attention to safety in travel.

Accidents may be minimized in number, (1) by reducing speeds of cars indefinitely; (2) by increasing braking power; (3) by the introduction of some form of fender or protective device; (4) by the selection of employés who will exercise care in the handling of cars; and (5) by the education of the public itself to treat the cars with respect at all times. Speeds will increase rather than decrease, for the constant effort is and will be, in America, at least, to save time at the expense of concurrent disadvantages such as even that of injuries to passengers and wayfarers, and if the proportions do not rise to extraordinary figures, the public will not suffer the carelessness or misfortune of the very few to interfere with the advantage of the immensely greater number. The remedy must be sought, therefore, in the other directions named, and will, as a matter of fact, be found in the combination of all. The public, whether on foot or in vehicles, is daily learning to keep out of the way of street cars, and the lesson of true economy of good employés has been well learned by street railway companies. No entirely satisfactory braking system of general application has yet been found, but the power of mechanical brakes has been enormously increased since the advent of electricity, while air- and electric-brakes for the higher speeds of interurban work have been developed, not perhaps to the highest point possible to reach in the future, but to one of present commercial and effective value. Fenders are yet a necessity, though a troublesome one, and it is hard to see how their use can be avoided even with the best braking appliances.

THE MANAGEMENT OF EMPLOYÉS.

It is within the power of the street railway manager to exert an influence for good or for evil—towards better things or worse—in the lives of hundreds or thousands of employés. He can arrange their hours so as to keep them constantly on the move between home and work, or so as to give them long free periods of time within desirable

hours. He can harass them with a multitude of rules, or deal with them as reasonable beings with comparatively few rules. He can make them loyal and enthusiastic in the service of the company, or disloyal and indifferent to its interests. Upon his treatment of employés depends the success of his administration more than upon any other of its features.

The new street railroading of to-day has brought into service a much more intelligent grade of employés than was found in old horse-car days. Then it was only necessary that a driver should be able to handle horses with reasonable care and to maintain the schedules through the streets. The conductor was watched with the most jealous care to prevent dishonesty. Uniforms were rarely seen, and the morale of the men was undeniably poor.

To-day, the entire force of employés, particularly in the transportation department, is composed of trained men, neatly uniformed and with quick and intelligent minds. They are and must be smart, "snappy" and businesslike in the conduct of their work. The conductors and motormen must know many things about their cars, which were never required from the horse-car force, since blockades must be prevented and the road kept in operation at all hazards. As a consequence, the present employés can be made to feel proud of their work and their opportunities. The organization is more complicated, the chances for promotion are better, and the conditions are in all respects improved. The most successful managers of to-day have put their systems far beyond the danger of strikes by making friends with their men, and putting certain influences into play among them, which enormously increase their *esprit de corps*.

The most important of these influences perhaps is that of increase of pay with length of service. In the old days, the wages of a conductor or driver were no greater to the man of twenty years' service than to the six months' fledgling. All were treated alike, the theory being that the *work* was the essential thing, not the *man*. As a consequence, disaffection was easy to create in a body of employés.

The long service employé felt, indistinctly perhaps, but none the less certainly, the injustice of putting him on a level with the new man, and felt, too, that there was nothing for him to look forward to in the future. All men were equal in the labor meetings, and a knot of the disaffected could sway the entire body of employés.

It is easy to understand the restraining influence brought about by the adoption of a graduated wage scale in a body of employés of this character. Suppose, for example, that this scale runs from $1.75 to $2.25 per day, the minimum being received for the first year's service, and a 5-cent per day increase being granted for each subsequent year, so that only after ten years' service will the $2.25 rate be obtained. We have, therefore, in such a force ten different bodies of men, each growing better and better satisfied, and more and more conservative as the years go by. Each takes a pride and pleasure in every increase of pay, looks forward to still better things, and considers the entire wage scheme reasonable and just. The chances for disaffection are confined to the newer men and the influence of all the others is a restraining one not only because of their self-interest, but also because of their longer experience with the company's methods and the consequent value of their advice. In the remote contingency of a threatened strike, the employés cannot go before the public with as strong a case as they could were the average wage rate $1.75 or $2, for example, since the company can show that it is really paying the higher wages demanded for experience and ability, and it is the new and untried men who are making the trouble.

Another influence of much the same general character is the adoption of the "service stripe" plan of recognizing length of service. The man who carries on his sleeve one, two, three or four stripes, signifying an equal number of years of service, or one or more gold stripes, signifying five years each, feels the responsibility of his position, and feels a self-respect which shows immediately in his care of the traveling public, and which in turn commands respect from that public. He is identified with the company, its interests are his and will be guarded. The officers of the com-

pany themselves should have, and do have, as a matter of fact, great respect for the older employés, and the entire force, from the president down, is welded together more and more closely as the proportion of the long service men increases.

Still another good influence among the men is that of promotion to positions of higher responsibility, and the sooner street railway companies realize this and put the principle into practice, the better will be the results they obtain, and the more nearly will they approach the stability and strength which the railroad industry has gained by the security in tenure of office and chance of promotion which has been for many years granted to railroad employés.

The principle of competition in the conduct of the street railway business has not as yet been introduced to nearly the extent that its value warrants. In the maintenance department, for example, piece-work as against time-work could probably be adopted with considerable advantage. A man will always work harder and more intelligently and adopt better labor-saving methods if the fruits of his work are to be given him in greater remuneration, and while careful inspection of such work is of course necessary, the conditions under which street railway repairs are carried out are such as to make such inspection feasible and efficient. The experiment has been made in one or two cases with excellent results.

Another place where the competitive idea can be introduced is in the management of the power used by cars. It is well known that motormen, as a rule, waste power enormously by the improper handling of controllers. In many cases this is done carelessly, without much thought of results. In others it comes from a disposition to play with the immense force at the command of the motorman by the movement of his hand. The results of this misuse of the controller are seen not only in the power cost, but also in increased depreciation of motors through constant use of excessive currents. Now the very simple plan of placing in each car a wattmeter to measure the power which is used by that car, and of taking regular readings of this wattmeter at the end of each run, has accomplished in one or

more instances, and would accomplish in practically all, remarkable results in the saving of power and depreciation, for the moment that a motorman is called to account for using more power in going over a route than another motorman uses, that moment he begins to be more careful. In one case recently made public, a saving of 33 per cent. in the cost of power was effected by this simple method.

The street railway employés' associations, with their corresponding club rooms, gymnasiums, baths, libraries, and monthly and annual entertainments, together with the provisions for death benefits, etc., tend to bring the management and the men into closer union, and are always to be encouraged as valuable adjuncts to the regular work. The library feature, which has been lately introduced on at least one large system, brings the home influence into play in behalf of a management, tending, however slightly, to cause the women of the family to exercise a restraining influence over the men in times of threatened strikes.

Broadly speaking, the modern street railway management, as distinguished from the older forms, brings men into closer communion with the official staff and creates in them a self-respect and manliness of character which is the best possible security against trouble. Those managers who have adopted these broad-gauge methods and have been genuinely solicitous for the well-being of their men, have been successful to a remarkable degree in securing the personal loyalty of the latter and in strengthening their own position and that of their company in the community.

THE ADVANTAGE OF COMBINATION.

The public gains, or ought to gain, with combination of municipal service enterprises. No principle in practical sociology is better established, perhaps, than that which grants to public service industries in municipalities the right to be regarded as "natural monopolies." It can never be to the permanent advantage of the people to have two lines of street railway serving the same territory on the same or parallel streets, while it is a distinct disadvantage to have separate companies serving different sections of the city. A transfer system between independent companies is

an impossibility on any fair basis, while the almost universal result of a consolidation of several different companies in a single city is the immediate granting of transfer rights, and an immense saving to the people. This one advantage alone is a sufficient *raison d'etre* for consolidation, but in addition to this there are others. The entire transportation of a city can be operated by a single company on broader lines and to the far better service of the people than can be done by two companies. Economies can be introduced and more liberal expenditures in other directions made possible, through routes can be established along the lines of customary travel, and in many other ways the people will be benefited.

The economies effected in the street railway administration are numerous. Instead of several power stations one or two of the best ones only may be kept in service and the cost of generating and distributing the current may be minimized. A better service may be given with a smaller number of cars than before, the official salary list may be reduced, the principle of division of labor may be introduced into shops, repair force, etc., and the day when fares may be made lower to the people will be brought distinctly nearer.

There is also much to be said in favor of the consolidation of street railway and electric light and power interests. The great difficulty with electric lighting stations to-day—a difficulty which is keeping up the price of light and power to materially higher figures than ought to be possible of attainment—is the fact that the stations can be loaded up to their capacity for but a few hours out of the twenty-four. This puts the working forces to a disadvantage, leaving them comparatively idle for many hours, and reduces the economy of the engine or leaves a part of the plant idle, which thereby earns no interest upon its cost. If the market for power can be increased and the loads distributed fairly evenly over the day, the cost per unit of power delivered will be far less than at present, and the price can be correspondingly reduced. The consolidation of all electric power-using interests will tend to bring about this result, and is, therefore, to be favored on the grounds of public as well as on private gain.

THE PROBLEM OF MAKING A FAIR BARGAIN WITH THE CITY.

I have purposely left this most important problem till the last, because it is only through a more or less clear understanding of the nature of the other problems hereinbefore discussed that the true character and difficulties of this one can best be understood. There are, and will unfortunately continue to be, a great many false theories and ill-advised schemes put forward to solve the problem of how to best handle municipal service enterprises and to relieve the tension now existing between municipalities and private companies. The truth is that there is no one method of universal application. It is as foolish to assert that municipal ownership of everything in sight will bring the millennium immediately as it is to hold that municipal ownership has no place whatever in the management of public service enterprises. There is a sharp distinction between that class of services which a city has to itself use in whole or in part, such as, for example, sewerage, water-supply, gas or electric light, etc., and that class which it does not use, such as transportation. An attempt to control the former class may be defended on the ground of wise economy in city expenditures. An attempt to control the latter has for its basic purpose an idea either of obtaining revenue by indirect taxation or of giving a service to the people at actual cost.

Under all circumstances and with all kinds of enterprises, it is true that municipal corporations in which responsibility for results is so greatly subdivided cannot theoretically, and do not, historically, conduct business enterprises with economy or efficiency, while even more important than the question of mere money-saving or waste comes the undeniable fact that the trustees of municipal funds cannot possibly manage those funds on broad lines, or with the calm confidence in the future justification of present expenditure that private capital would have. The taxpayer would not suffer the imposition of present burdens for the benefit of posterity, at least without a storm of criticism which would render the position of the trustees difficult or untenable.

The transportation enterprise, particularly, is one where investment must be made without regard for present profit if the growth of the city on right lines is to be kept up. For this reason, and entirely independent of the mere question of possible revenue to be derived by a city from the operation of its street railway system, I believe firmly that it would be utterly unwise to place the control of a city's transportation agency in other than private hands. I believe that in practically all cases the true solution of the problem of relations between a city and its street railway system is found in granting to the latter private ownership and operation, complete monopoly, perpetual franchises and a system of perpetual profit-sharing with the municipality, joined to a remission of charges to the public if and whenever profits come to be sufficient for that purpose.

By a policy of this kind it is possible—

(1) To avoid pledging the city's credit for making the necessary original investment.

(2) To place upon private capital the burden of all losses realized or contingent.

(3) To obtain for the city an equitable share of all profits actually realized.

(4) To avoid the creation by the city of a complex bureaucratic organization with its attendant political dangers.

(5) To secure for the benefit of the municipality, its people and the private capital invested the undeniable benefits of private management as affecting profits, perfection of service and direct responsibility.

(6) To secure for the municipality, the people and the private capital invested the true pro rata shares of each in the additional profits coming with municipal development in the future.

When all the safeguards possible to devise shall be thrown around a municipal contract of this character, it will be found that the street railway problem in that particular city is solved for all time, and in a fair and equitable manner. Thenceforward the municipal government and the street railway corporations will work *together* to build up and develop on its broadest lines the municipality of whose interests they are at once guardians and servants.

"Railroad" Meeting, March 28, 1899.

THE ELECTRICAL INSPECTION OF STREET-CAR EQUIPMENTS.

BY ALBERT B. HERRICK,
Consulting Electrical Engineer.

As electrical machinery is becoming such an important factor in modern civilization, the maintaining of this machinery requires indirect methods in order to make visible, through the means of instruments, the electrical conditions of the apparatus or machinery.

Nowhere in the application of electricity is the electrical inspection more necessary than in street-railway equipments; here the motor is operated with exposures to weather, mechanical jars, heating, and severe electrical and mechanical strains; and the predictions were when the first roads were operated, that this system was impracticable, and a preposterous engineering proposition.

The development of accurate methods for finding these hidden electrical troubles in an equipment has been urged upon me, for the reason of the high cost of the electrical repairs on street-car equipments. These aggregate many million dollars per annum in the United States; and to bring this forcibly to your minds, in two of the roads which I have examined, I have found the cost of the electrical repairs of a 22-foot double equipment to cost the same as those of an 80-ton locomotive on the Pennsylvania Railroad, the same distance, and carrying a full train of freight cars.

The wiring of a car by which the current is conducted through the equipment is of necessity not a fixed nor rigid system. The resistances which are used to control the flow of current through the equipment, on account of their limited weight and space, will not carry the current continuously, and careless motormen may injure the resistance by improper handling of the controller.

The controller, which is practically the nerve center of the equipment, reflects in its depreciation all the latent defects in the equipment.

After carefully inspecting, electrically, a large number of equipments, one feels very much like diagnosing the different diseases which are inherent in the various equipments, and also separating from these, those diseases which are developed by forcing or the improper handling of the controller, which are attributable to poor motormen.

There is another class of diseases which have their origin in careless inspection and careless maintenance of the equipment.

It is not so much my intention to analyze the diseases to-night, as to describe the means by which they are detected and located.

Following out our original anatomical idea, it is easiest to look at the various ramifications of the current flowing through the equipment as a circulating system, with the controller as a deflector for these different circuits through the equipment. *Fig. 1* shows a very common form of series parallel controller with the connections it makes with the apparatus on the first notch; with each movement of the controller handle the current is changed in its path. The sequence of changes made by the controller as it passes from the first position to the last, including nine positions, in this case, is as follows: The first position starts the current flowing through the electrical circuits of the car, and the car should now move. A large amount of energy is lost in the resistances R_1, R_2, R_3, R_4, which choke down the initial current on the motors. From the first step to the second, cuts out $4\frac{1}{2}$ ohms in a standard equipment of this type; from the second to the third step cuts out $1\frac{1}{2}$ ohms, and from the third to the fourth step cuts out $\frac{1}{2}$ ohm.

The motors are both in series and across the full potential between the trolley-wire and the ground. The rheostat, which is the resistance, that has just been cut out by the first three steps of the controller, after it has been installed on the car, is given very little attention; it generally increases in resistance with age. I have found many rheo-

stats over four times the resistance they should have been when new. The result of this increase in resistance is that the car will not start on the first step of the controller when the resistance is hot, or the car heavily loaded; for the resistance is so high on this step that the current is cut down below starting value; and when the second step on the controller is reached, the car will have what is known as the "kangaroo start." The reflection of this defect in the equipment is to increase the temperature of the motors,

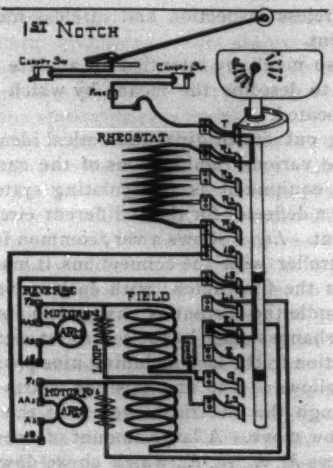

FIG. 1.

increase the strains on the motor, and increase the current demand on the station, and give a disagreeable acceleration to the car. This defect is more noticeable on those motors having a large starting torque. The motors which have a small starting torque do not show this defect so much in the start and car acceleration, but struggle along under this excessive condition until they retire to the repair-shop, damaged.

I have expanded on this point somewhat, because it does

not seem to be generally known that this condition is primarily the cause of a large number of break-downs in equipments, which condition may be caused by burnt-open or high resistance in rheostats. A low resistance on the first step of the rheostat has identically the same effect on the equipment as the first step being too high, and the second step being normal. Where repair accounts were kept against individual cars in street-railway operation, I have often found the high cost of repairs on some cars due to just this rheostat trouble; the controller, armature and

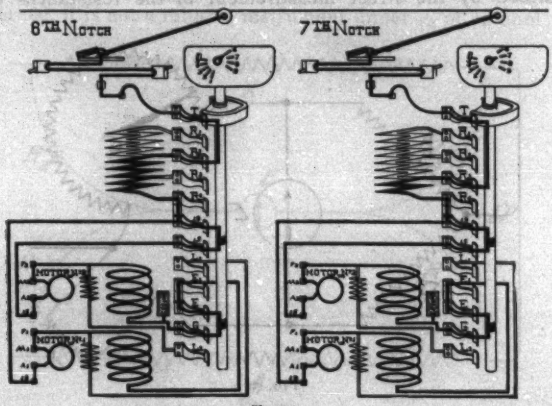

FIG. 2.

fields being continually repaired, while the rheostat, which is the real cause of the trouble, is left unmolested.

Rheostats are also much more heavily strained on roads possessing considerable grade, and they tend to increase in resistance and prevent the most effective operation of the equipment; and this condition increases materially the watts per car-mile required on grades where starts are frequent.

In the type of controller under consideration, the resistance between the second and third steps, R_2 and R_3, being high, is not of much importance in this part of the opera-

tion of the controller, if it is not so high that the car loses acceleration; but if we follow the operation of the controller in *Fig. 2*, you will notice that on the sixth notch in this position the motors are connected in multiple; and this second to third step in resistance is again cut in series with the two motors in multiple. Here, if the second step is high, the equipment will lose acceleration, and when arriving on the seventh notch, the motors will again be subjected to an abnormal flow of current.

It is evident that these conditions can only be determined by the direct measurement of the resistances of

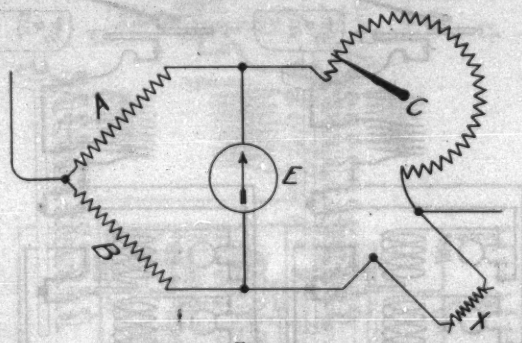

FIG. 3.

these circuits as made by the controller; but the resistances of these circuits possess peculiar features which are not common to a purely metallic circuit. We find contact resistances in the controller and carbon-brush resistances in the motor. The contacts give extremely variable and unreliable results when measured with a low-potential test current. The carbon-brush contact will often appear as an insulator under this condition, and a poor controller contact will give a constantly varying resistance.

In order to bring the contact resistances down to normal, it is necessary to pass considerable current through the equipment when testing, and it is most convenient to ob-

tain the current from the railway circuit. But when we use a current varying as the ordinary railway current varies, and yet discover the variation of resistance as low as .005 of an ohm, another difficulty confronts us, and neither a bridge method nor fall of potential method are applicable to this work.

In any bridge method the measurement of a resistance also includes the contact resistances by which this resistance is placed in the measuring circuit, as at *Fig. 3*, and due to this varying quantity introduced into the bridge method, it is not a reliable instrument under $\frac{1}{10}$ of an ohm;

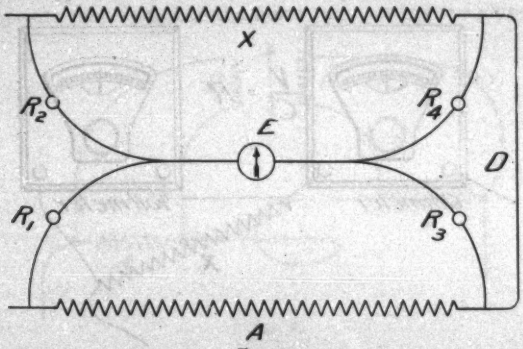

FIG. 4.

nor in the other extreme, can the bridge give quantitative results over 500,000 ohms. For these reasons it is useless in measuring low resistances with any degree of accuracy which will admit of a definite analysis, especially in those resistances met with in fields and armatures. No multiplying arrangement can increase the accuracy of any measurement external to this instrument.

Thompson's method of measuring resistances which is applicable to low resistances, is extremely delicate and of general use for this purpose; but there is one very important condition necessary in using this method; that is, there cannot be any appreciable resistance between standard *A* and

the resistance *X* under measurement, as at *D* in *Fig. 4;* for in that condition there would be considerable fall of potential along the measuring lines, which will interfere with the accurate comparisons of the resistances, *A* and *X*, under measurement, and in car inspection it is impossible to have the standard and resistance under measurement adjacent to each other. The volt-meter and ampere-meter method, where connected as at *Fig. 5*, will give the resistance sought, by dividing the volts read by the amperes flowing. But in measuring an inductive circuit, such as a field or armature of a motor, we find that with the voltage falling, the resistance between any inductive terminals is apparently

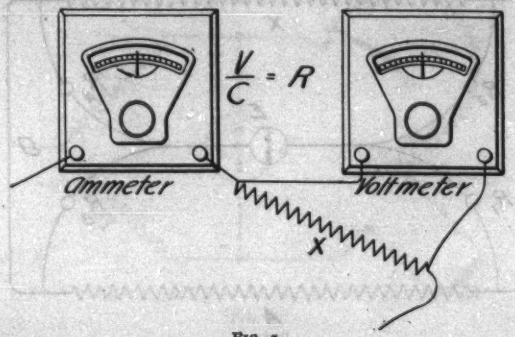

FIG. 5.

lower than its true resistance; and with the potential rising, the resistance will be apparently higher than the true resistance measured. This method is too tedious and unreliable for the purpose of accurately diagnosing equipment troubles, as, to use this method, we have to balance our circuits inductively as well as ohmically in using the trolley circuit in equipment testing; but to make all this practical and of general utility, the system must be so devised that the measurements and determinations can be made quickly, and not necessarily by one skilled in the art.

The author, after years of experience, has had to abandon the above methods, for they did not produce sufficiently con-

cordant results to make the analysis of an equipment positive, and he has developed the differential method shown in *Fig. 6.* This is nothing more than separating the differential coils of Kelvin's method, electrically, so the resistance between *A* and *X* would not interfere with the accurate comparison of two resistances.

Another condition necessary in the development of a system is the keeping independent from each other the different tests requiring different connections made to the testing apparatus, so an inter-locking system had to be devised by which means the test under consideration could be connected up only when the dial was turned so the pointer was opposite that test, then the holes for inserting the plugs in

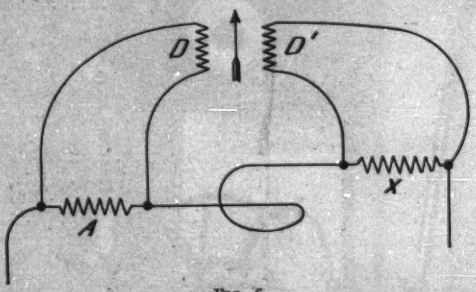

FIG. 6.

this test registered with the proper receptacles, and the plugs could be inserted for this test, and no interconnections could be made which would injure the instruments used in these tests.

The semi-portable apparatus, known as *Form D*, is shown here in *Fig. 7*, which combines besides the inspection tests, all other well-known ampere-meter and volt-meter tests which are required on the line, car operation and electrolysis. The testing set, including only the inspector's test, is a much more portable affair, and can be readily carried from car to car. It is very easy to make an electrical inspection of an equipment in one minute, when proper arrangements are made to expedite the test; and a testing set can be taken to any part of the road where the cars can

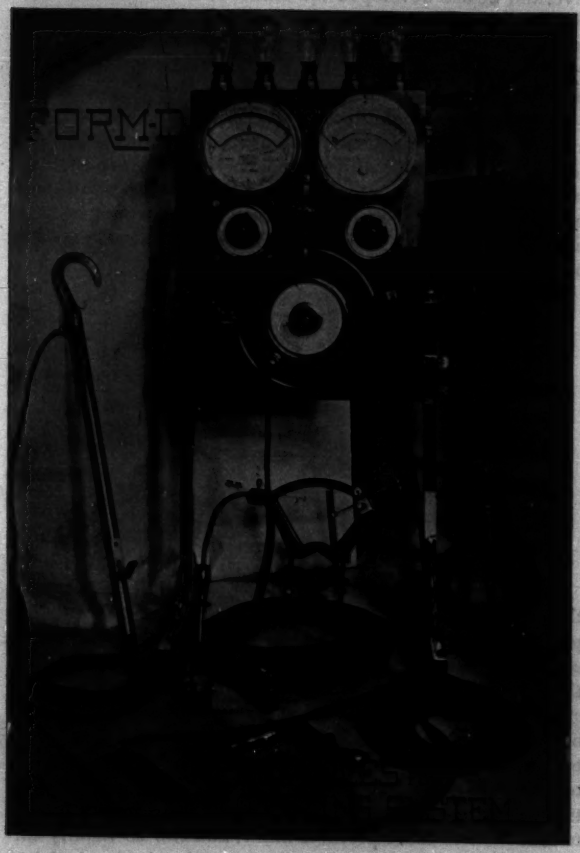

FIG. 7.

be delayed, and this test can be made on each car by holding it for one minute.

The inspection test consists simply of measuring the equipment up on each notch of the controller, and every road fixes its maximum and minimum standard for each type of equipment, there being considerable range between the allowable maximum and minimum at first.

To maintain an equipment means to keep the different controller points within standard values, and any part which departs from standard value can be immediately repaired at small cost before the more serious secondary effects have rendered the equipment a cripple.

I show a plotted curve (*Fig. 8*) of ten identical equipments which were inspected on a fairly well operated road, and it shows quite a variation in rheostats, and also two burnt-out fields and a poor brush holder. A straight line is drawn through these tests in order to show where the standard should be. It will be noticed that there are high rheostats in several equipments, and it will also be noticed that in equipment No. 23 the high rheostat has resulted in the burning of the field of No. 1 motor. It will cost five times the amount to replace the field that it would to repair the rheostat, and it is only by careful inspection that these primary troubles can be detected in time to prevent a more serious loss.

The ageing effect on the different types of equipments tend to lower in some and to raise in others the resistance of the rheostat. The field resistance will fall slightly, owing to the annealing effect on the wire, but if the resistance falls below 1 per cent., it is due to turns being short, or the carbonizing of the wire insulation known as baked, which allows the current to pass between the adjacent turns through the carbonized cotton insulator instead of around the turn to produce the magnetic effect on the field.

The result of this is to make the armature revolve faster in the weakened field, and the armature will become overloaded in its effort to run the car, and also to carry the other motor; in this way if the equipment is operated the result will be an armature burnt out.

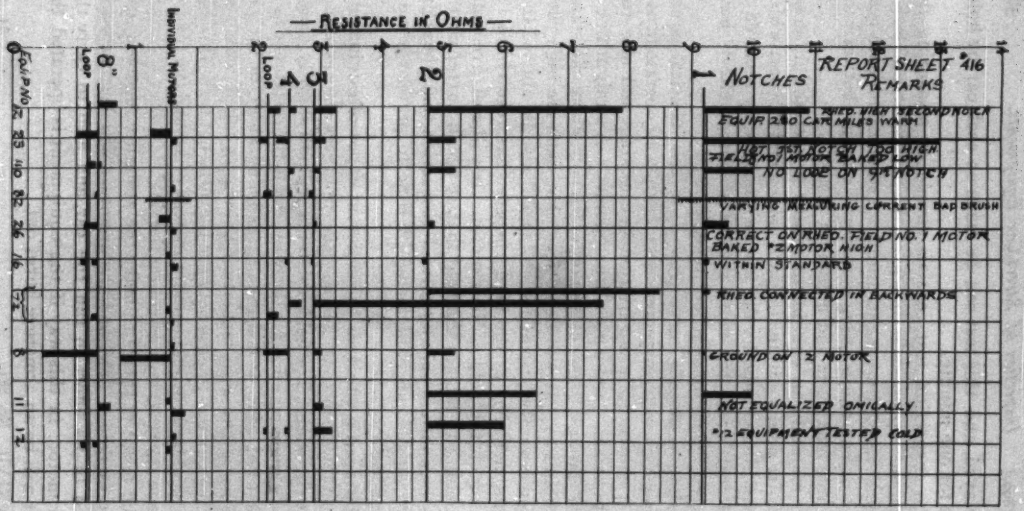
—RESISTANCE IN OHMS—
REPORT SHEET 416
NOTCHES
REMARKS
EQUIP. NO.
8" Loop
Interval Notches
Loop
EQUIP 260 CAR MILES WARM
NO LOAD ON 9TH NOTCH
VARYING MEASURING CURRENT BAD BRUSH
CORRECT ON RHEO. FIELD NO. 1 MOTOR
BAKED #2 MOTOR HIGH
WITHIN STANDARD
RHEO. CONNECTED IN BACKWARDS
GROUND ON 2 MOTOR
NOT EQUALIZED OMICALLY
#12 EQUIPMENT TESTED COLD

FIG. 8.

In one case in which I inspected the cars, the armature winder, who was an excellent worker, had been discharged for the reason that his armatures would not run more than a few hundred miles before being burnt out. I found that defective fields were the cause, and after replacing the bad fields in these equipments, the armature winder was reinstated, and there has been no trouble since.

An undiscovered baked-out field is one of the most prevalent causes of motor troubles. A number of methods of winding and treating fields are now in use, which have for their purpose the preservation of insulation between adjacent turns of wire, such as winding the wire with asbestos under the cotton. Care must be exercised in using this wire, as some of the forms will not hold the proper number of turns with this increased size, due to the asbestos covering, and if the proper number of turns are put on the form the field spools will not fit in the motor.

Another method used is to slush these coils as they are being wound, or dipping them, after they are wound, in a solution made up of chalk, magnesium-oxide and water to the consistency of whitewash; and this foreign material being introduced into the winding, when baked, hardens and forms a mechanical barrier between the adjacent turns and prevents their short-circuiting.

Other methods are practiced, such as dipping the field coil into varnish or insulating compounds. These different methods all have for their purpose the introduction between the adjacent turns of wire of a non-carbonizable insulator.

The field coils must be well baked after the application of any of these methods in order that any moisture or alcohol may be driven off before the coils are used. It has been the practice to pass current through these coils and heat and bake them in this way; but when water or alcohol is present, internal electrolysis is set up, which forms internally a conducting copper salt, and this destroys the insulating properties of the mediums employed. Another point may be mentioned here in regard to baking where armatures and fields show low to ground after being baked—the baking oven is completely enclosed, and any moisture

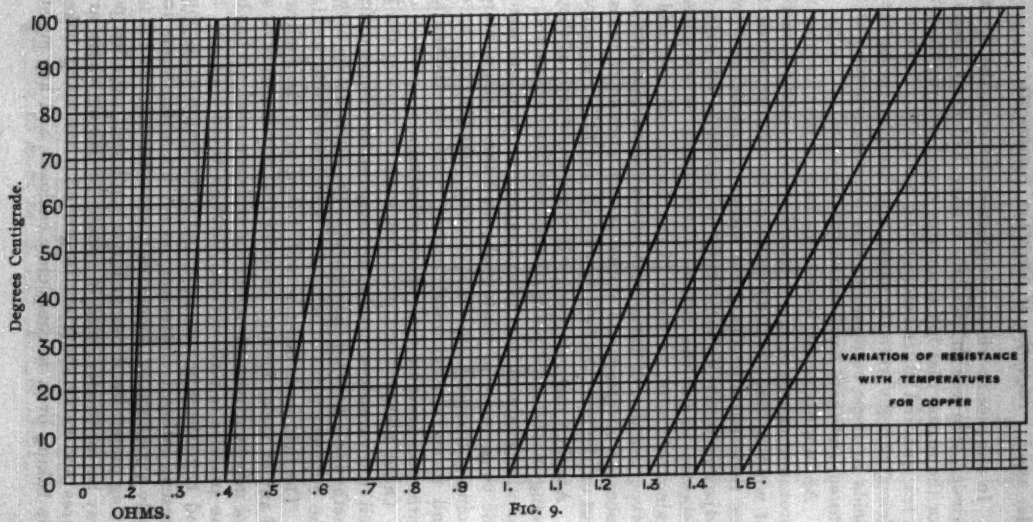
Degrees Centigrade.
100
90
80
70
60
50
40
30
20
10
0
0
.2
.3
.4
.5
.6
.7
.8
.9
1.
1.1
1.2
1.3
1.4
1.5
OHMS.
VARIATION OF RESISTANCE
WITH TEMPERATURES
FOR COPPER

FIG. 9.

excluded from the coil is held in the air. A baking device having no ventilator is really a steam box, and not a baking oven, and high insulation cannot be obtained unless ventilation is provided to the oven.

The best way to measure the temperature of a motor is to measure its resistance when hot, and for each degree Centigrade rise in temperature of the field the resistance will increase 0·38 of 1 per cent. *Fig. 9* gives the increase of resistance for each ·1 of an ohm to 1·5 ohms, and up to 100° Centigrade. The drops in volts across one field when the equipment is running is the best method of testing whether the two motors are taking their loads equally, when they are connected to a series parallel controller. When the motors are in series, they are both taking the same current, and the drop across the field should be reduced one-half when the motors are thrown to multiple, and the same current passing in both cases. If the voltage drop is not cut in half under this condition the motors must be out of equalization, 8 per cent. being the maximum difference in equalization allowed to pass. With the differential method each coil takes the drop off of one field of each motor, and the hand stands at zero in case of equalization. If the hand departs from zero as the speed of the equipment increases, the lack of equalization is due to difference in air gaps of the two motors. If there is a constant deflection for all speeds, the non-equalization is due to the unequal resistance of the two motors in multiple.

In the tests on the armature and its commutator, which is the most delicate part of the equipment, and first succumbs to ill usage or lack of proper inspection of the equipment, the different diseases met with in this part of the motor, are grounds, short-circuits, open coils, broken leads, and broken-down insulation in the commutator, and especially short-circuiting through the commutator ring. Their detection is rendered easy by a bar-to-bar test on the armature. *Fig. 10* shows the method of applying this test to the armature, a brush-holder yoke is clamped to the shaft of the armature, and insulated brushes bear on the bars of the commutator; by moving these brushes around the commu-

tator, the indication of the instrument will be constant in all positions of the brushes; but if an armature is misconnected, there will be a change in values when the brush rests on that commutator bar to which the misplaced lead is connected. Two bars which are short-circuited together when they lie between the four testing brushes will give readings that will be lower than normal. A ground in an armature can be located when one of the measuring terminals is connected to the shaft. The grounded coil connects to that commutator bar which gives the lowest reading on the measuring instrument, when the measuring contacts are

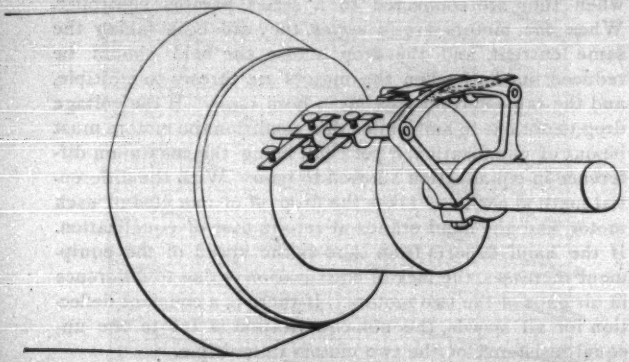

FIG. 10.

revolved around the commutator. Where the insulation is to be measured, the same connections are kept on the armature as for ground, and the test plugs are removed, and the dial turned to insulation test, and plugs inserted in the exposed receptacles; the insulation is read directly in megohms on the insulation scale of the instrument. *Fig. 11* shows method of connecting to the field.

The controller has troubles of its own, such as poor contacts of the fingers, short between fingers, grounds, burnt-out segments and misconnections; also the insulating partitions between fingers become carbonized and cause an arc

which destroys the contact fingers. Many imperfections in the controlled circuits leave their imprint on the controller. Several of the most prevalent indications will be mentioned, such as the burning of the second resistance contact and the first resistance contact being bright will indicate an open connection in the first resistance step. A bad flash at either loop contact, where loop is cut around the field, indicates an open or poor field connection. In this way many things can be observed in connection with the equipment, and it requires that a successful inspector be keenly alive to all the little external evidences of the internal troubles.

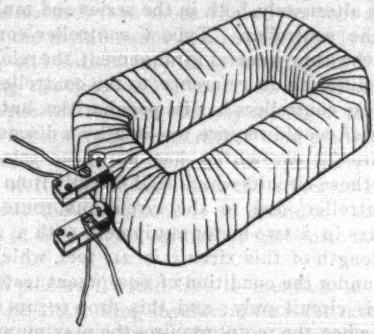

FIG. 11.

And to aid him, I have produced diagrams of connections divorcing the essential apparatus of the equipment from the intricate wiring system so that the conditions of cause and effect can be quickly arrived at.

The controller diagrams that we have studied of type *K* in *Figs. 1* and *2*, show one of five different types, placing them historically. First was the rheostat control, which consists of a resistance in series with one or two motors, as the equipment requires, the function of the controller being to close the circuit and vary the resistance in series with the motors, and in this way controlling the current delivered. The next step in the art of equipment regulation was to first place

both motors in series, and also in series with the resistance; after this resistance is cut out the motors are automatically placed in multiple. At this point there is a divergence in connection; one type, such as the *K* controller, places part of this resistance in series with both motors in multiple. The type known as *G* controller in passing to the multiple position places one motor directly across the line potential, and the full resistance in series with the other motor, which is cut out in the succeeding notches of the controller, until both motors are directly across the line. Type known as *No. 14* controller has a separate resistance step in series with each motor; when the motor is in series, these resistances are cut out alternately, both in the series and multiple positions of the controller. Type *C* controller comprehends somewhat the same general arrangement, the relation of the parts only differing in reference to the controller contacts. Each of these controllers has its peculiarities, but to go into them in detail would require too lengthy a discussion.

The wire for car wiring has not been selected large enough in those circuits which lead directly from the motor to the controller, due to the circuitous route that the current takes in a two-motor equipment with a 20-foot car body, the length of this circuit is 217 feet, which of No. 6 wire gave under the condition of equipment tested 12 volts drop in this circuit only; and this drop occurs under the conditions when the motor requires the maximum potential delivery at its terminals; and a few additional dollars spent in the internal wiring of a car would accomplish the same results as hundreds of dollars spent on the line.

The application of electrical inspection of equipments brings out some very queer conditions caused by the car wiremen not fully comprehending the wiring diagrams furnished. In one case I found a number of equipments with both loop boxes connected in series around the field of one motor. Another case I found all the rheostat boxes connected in backwards; that is, the low resistance step connected to the first step, and the high resistance step cut out just before the motors were put across the line. Another case in No. 14 controller, I found where one resistance had

always been short-circuited by a misconnection, and the equipments had been working under this condition for several years.

Briefly summing up my experience of the testing of over 1,000 equipments, including nearly all the types extant, I find that the principal weak points are:

(1) That the two way connectors are responsible for a great deal more than their share of trouble, and that every break in the continuity of the conductor system reduces the reliability of the equipment for continuous operation.

(2) That a motor is not any better than its field.

(3) That careless brush inspection is responsible for more burnt-out armatures than those caused by poor motormen.

(4) That the maintenance of an equipment is much more economical and satisfactory than trusting to Providence and awaiting the time until it breaks down; in other words, it is far better for a street railway manager to operate a sanitarium for his equipments rather than a hospital.

The vitality of an equipment rests entirely upon the excellency of its insulation; and the trend of recent improvements in the equipment is to abandon those insulators, which in time either oxidize or carbonize and become conductors.

One final pointer I would like to mention in regard to high-potential alternating insulation tests for railway apparatus, which is generally considered a satisfactory method because it shows so many faults not indicated by other tests, but the application of this high-potential method, with depleted insulation, usually develops the fault which it detects and curtails the natural life of armatures and fields.

Mining and Metallurgical Section.

Special Meeting, March 23, 1898.

BUILDING-STONES—ELEMENTS OF STRENGTH IN THEIR CONSTITUTION AND STRUCTURE.*

By Alexis A. Julien,
Columbia University, New York.

(*Continued from p. 286.*)

III. TENSION OR STRAIN.

We must again recognize, I think, as an essential element of strength, a certain balance of tension or strain among the mineral components of stone. Any disturbance of this by increase, by loss, by expansion or by contraction, by any change, tends to injure the tenacity, coherence and permanence of the aggregate.

Above all other bodies in nature, a mass of rock seems to our eyes to be the most passive and inert; "as dead as a stone," is the common saying. Even though we have learned of the mighty activities by which a rock has been generated and modified—of water, of wind, of chemical action, of fierce volcanic heat—all the violence of these processes is popularly supposed to be long since extinct, all the energy long since dissipated. Yet there is abundant evidence to the contrary; that a vast amount of this force still remains latent, but all ready, after ages of waiting, to issue in active form when released by certain conditions. Rather should we see, then, in every lump of stone a storehouse of enormous energy, any portion of which, if suddenly evolved, may even become explosive. In the crust of the earth beneath our feet, we find ourselves upon a vast unannealed ball, within which not only every molecule lies in active vibration, but fragments of the mass are continually leaping

* Abstract published in *Stone*, 1898, and elsewhere. Reference has been made in the notes to the more important statements which have appeared in the literature of the subject, during the year since the reading of this paper, concerning points discussed herein.

into violent motion. The phases of these stresses near the surface have been produced by crystallization, by subterranean movements and by present physical conditions.

(1) *Tension or Strain by Crystallization.*—A glance at the magnified structure of ordinary building-stone, such as that of a granite (*Fig. 15*),* unveils to us a struggle among its crystal components—quartz, orthoclase, albite, hornblende—all thrusting and straining together for growth within the original plastic mass or magma, each from its own center of pressure, until the process of consolidation and rigidity (usually accompanied by contraction) came to an end. The universal failure of completion here, in this mutual conflict, and therefore of satisfaction of energy, is shown by the total absence of individuals which have perfected their crystal-faces. Not a prism of quartz terminating in its shapely pyramids, nor rhomb of feldspar, nor brilliant hexagon of mica delights the eye. All is imperfection and disorder. The combatants lie before you, interlocked and jammed together, with rough or irregular outlines which bear little or no resemblance to the crystal forms of lovely symmetry which would have developed in isolation—those which actually lurk in sheltered "vugs" or have sprung into form within slowly cooled lavas. At the bounding-planes between these individuals, we find evidences not only of contact and pseudo-welding, but often, if not generally, of mutual pressure or stress and consequent strain. Many facts testify that, in the act of consolidation and crystallization, change of volume occurs. In the metals and artificial alloys, we are familiar in the arts with the contraction, which, at that moment, occurs in lead, and with the expansion, in bismuth and in type metal; also, in the well known constituent of all stones, water, with that rapid and violent expansion, near and at the point of freezing, which rends asunder the most powerful rock.

The student of petrography also finds, under the microscope, ample evidence of the survival of these centers of still active stress. Thus, in a crystal of garnet, found sur-

* For illustrations, see the *Journal* for April, 1899.

rounded and locked fast in a plate of mica (*Fig. 16*), the latter dense mineral is seamed by cracks radiating from the enclosed intruder. Sometimes the delicate test of polarized light reveals, too, that the very molecules of the strained garnet, entities minute far beyond microscopical detection, have, by some mystic change under the stress, so reversed their very form and nature as to throw back waves of light in a strange new way, causing the garnet to glow within, where, under ordinary conditions, only darkness would prevail.

So again in those fragmental stones which possess a crystalline cement, it is interesting to note an extraordinary separation of grains, as if they had been wedged apart (the interstices being wider than usual in the original sediment) by a strong force, during the crystallization of the interstitial cement—it may be, of calcite in an oolitic limestone (*Fig. 9*), or of quartz in a quartzitic sandstone (*Fig. 10*), and still more in those sandstones of frequent occurrence in which much more quartz has been deposited around each sand-grain in their interstitial enlargement with crystal boundaries.*

As to the exact facts with each mineral, in reference to change of volume during crystallization, whether of contraction or expansion and to what degree, we have as yet little information from mineralogy or physics. But on these as yet unestablished data rest some important characteristics of stone. Such changes of volume, under confinement, might lead to a variety of conditions. With contraction to any extent, the resultant tendency would be toward loose granulation and imperfect coherence; with expansion to a limited degree, increased compactness and strength, or, to an excessive degree, undue strain, brittleness and fragility. In a homogeneous crystalline rock, such as quartzite, marble, dolomite or semicrystalline limestone (*Fig. 12*), if a slight expansion occurred during crystallization, or a decided contraction, either might tend to great compressive strength.

In a crystalline rock of heterogeneous constitution, such

* R. D. Irving and C. R. Van Hise, Bull. U. S. Geol. Survey, No. 8 (1884).

as granite, a known succession occurred in the development of its different minerals—usually, first, mica, then feldspars, finally, quartz (*Figs. 2* and *15*). Should the last constituent to crystallize possess the property of expansion, even to a minute degree, its grains would serve as wedges to jam and lock together all its neighbors. Should there come afterward to such wedges some sufficiently heavy pressure, some sudden tensile or compressive strain, some loosening by chemical solution and corrosion, some persistent touch of the finger of Frost upon this key, little wonder should the whole structure of the stone rapidly begin to fall apart. With certain kinds of stone, however, certainly formed by crystallization out of an igneous magma, such as many granites, all traps, etc., there is reason to believe that the remarkable compressive strength has been produced by the opposite process—contraction at the time of crystalline solidification. Professor Niess, indeed, in 1889, after careful weighing of all the evidence, was obliged to conclude that rocks expand on solidifying. But, more recently, C. Barus, as the result of careful trial of one igneous rock (the trap occasionally used for building in the vicinity of New York, Philadelphia and Baltimore), decides that "The present experiments show beyond question, I think, that at least for diabase this is not true. I find that this rock not only contracts between 3·5 to 4 per cent. on solidifying, but that such solidification is sharp and only apparently continuous."* Hoskins also concludes, "Certain known bodies (such as water) expand in solidifying; the solidification of such bodies is retarded by pressure. It is probable that the reverse holds true with the majority of bodies, including rock materials."† These considerations, though partly hypothetical, may suggest important practical results to be expected from physical experiments in this direction on other rocks and on the minerals common in building-stones.

(2) *Strains Produced by Subterranean Stresses.*—No facts are better established within the observation of the field geologist than those connected with contractile movements, dur-

* Bull. U. S. Geol. Survey, No. 103 (1893), 25.
† *Loc. cit.*, 847.

ing consolidation of rock-strata, and with their later displacements, in consequence of intense lateral thrusts in the earth's crust. The shoving and curvature of beds, accompanied by stretching on the convex side and by compression on the concave, but in each culminating in innumerable joints, fractures, faults, the sliding and mutual grinding of these fracture-planes, and, on a large scale, the very crushing up of layers into "friction-breccia," "brecciation-conglomerates" and sand, prove that, as J. D. Dana expressed it, "The rocks have been everywhere left in a state of strain, in consequence of the upliftings and foldings to which they have been subjected." From theoretical grounds, Hoskins also concluded: "The occurrence of actual tensile stress in rocks near the surface of the earth is by no means improbable. A bending of strata would tend to cause tension near the convex surface of the fold."* But of this fact many evidences are distinct to the eye, even in hand specimens; cracks radiating apparently from points of concentrated pressure; iridescent rifts, indicating slightly opened cleavage-planes, occupied by air-films; broken crystals, often long prisms, with faulted fragments more or less displaced; scales, plates and huge masses of mica, bent, crumpled, torn and distorted in waves and zigzag folds; great quartz and feldspar-crystals, nodules and pebbles, squeezed down into eye-shaped or lenticular flakes, whose agonizing stare, from cross-sections of porphyry or gneiss with the "augen-structure," testifies to the heavy load under which they have been pressed; quartz-pebbles in the conglomerates actually forced and moulded into each other, with the strange plasticity developed under intense pressures, even in materials the most unyielding; or both feldspar and quartz rolled out, as if mashed and kneaded from soft paste into thin plates and scales.

Investigation has shown,† in the case of strained metals, that the energy applied in the straining has been in large part stored up in permanent tensile stress or "potentialized,"

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* *Loc. cit.*, 874.

† C. Barus, "The Mechanism of Solid Viscosity," Bull. U. S. Geol. Survey, No. 94 (1892), 107.

e. g., to the amount of 50 per cent. in "glass hard" steel, strained to the point of rupture: 40 per cent. in brass; 25 per cent. in copper. On this point Van Hise states: "The experiments of Barus and the condition of the Rupert drops show that in strained minerals energy is probably potentialized,"* but elsewhere concludes: "While to some slight degree rocks are elastic when subjected to forces continuing for a short time, it may be doubted whether this property is of importance in considering the slowly acting and long continued forces of rock folding, except perhaps in the slight flexures of great extent. Single rock beds, when much deformed, are rather to be compared to a wrought iron bar, which when bent takes a permanent set. In this case there is an actual flowage of material or rearrangement of the particles to the new conditions."† But it is in the sedimentary strata of gentle flexure, and those too near the surface, *i. e.*, relieved by erosion from their original superincumbent load, that the quarryman resorts for the most easily worked and satisfactory materials for construction, and in these he constantly meets with evidences of unsatisfied stress. He finds them too in the still more compressed granites and crumpled gneisses and limestones, materials containing a far less proportion of yielding voids and probably possessing a higher modulus of elasticity than the arenaceous sediments. These are the very stones in which the petrographer finds, by means of optical tests under his microscope, the constituent crushed granules displaying "strain-shadows," in large part, or even universally, the significant optical tokens of active stress yet remaining.

As to the survival, therefore, in still active form, of part of the enormous force of compression which has been exerted, the miner and engineer, as well as the quarryman, have full proof in symptoms of strain still remaining in the strata among which they are working. A condensed review of observations of this kind (not easily accessible to the builder) may be pertinent, including some not yet recorded, in the hope of inviting further attention to such phenomena

* "Metamorphism of Rocks and Rock Flowage," Bull. Geol. Soc. Am., IX (1898), 300.

† "Principles," etc., 595–7.

in other quarries, with more definite determination of the amount of expansion, the direction and intensity of the expansion or thrust, and the actual changes thereby produced in the microscopic structure and physical characteristics of the expanded stone.

In mineral veins, frequent examples of violent strain have been observed, at least as far back as 1734. In the lead mines of Derbyshire,* the vein stuff, consisting generally of galenite, calcite, barite and fluorite, is divided into more or less vertical sheets or slabs by planes of *slickensides* or *cracking-whole*, which are beautifully polished, so much so in places as to possess the reflective power of a looking-glass, and usually ribbed or slightly fluted horizontally. Such sheets, when bared in the mining operations, fly to fragments with explosive violence, on being struck or even scratched by a miner's pick. "If a sharp-pointed pick is drawn down the vein with a small degree of force, the minerals begin to crackle, as sulphur excited to become electrical by rubbing; after this, in the space of two or three minutes, the solid mass of the minerals explodes with much violence, and the fragments fly out as if blasted with gunpowder. These effects have frequently happened, by which many workmen have been wounded. * * * In the year 1738 a prodigious explosion happened in the mine called Haycliff. The quantity of 200 barrels of the above minerals were blown out at one blast; each barrel, I presume, contained no less than three or four hundredweight." Mr. J. A. Phillips also observed that the explosions occurred after a portion of the vein had been undercut, and suggested that the removal of one side of a vein would leave the remaining side in a condition of strain, resembling that of a strung bow, with a tendency to bulge outwards into the workings. The undercutting would free, so to speak, one end of the bow. Mr. W. Bowman had noticed similar explosions of limestone in the Ecton mine and in the Clayton adit-level, where the beds are sharply contorted and crushed. Mr. Strahan concludes that in the veins "the spars are in a state of molec-

*A. Strahan, "On explosive slickensides," *Geol. Mag.* (1887), 400.

ular strain, resembling that of the Rupert's Drop, or of toughened glass, and that this condition of strain is the result of the earth's movements which produced the slickensides."

In coal mines of Great Britain, also, particularly where the strata are much faulted by dislocations, and at great depth, and in drifts in advance of the general workings of the mine, and in the lower part of the coal-seam, loud reports or "bumps" are of every-day occurrence, often accompanied by the bursting off from the sides of the excavations of large blocks or masses of coal, sometimes even displacing hundreds of tons. The noise made by such "explosions" or reports may be likened to artillery, and often causes men to run out of the place with alarm. During the operation of "holing" (under-cutting the coal-seam preparatory to breaking it down), the coal will keep on bursting itself off in little fragments from the face of the excavation with loud explosive reports, often putting the men's candles out. When the coal does this, it is said to have plenty of "life" in it, or "it keeps talking to you." These explosions, as well as the strange sounds heard when all work is suspended, rattlings, scratchings, knockings, etc., noises called "nackings" by the men, and also the subterranean rumblings heard on the surface, are attributed, not to escape of gas, but to "the upsetting, by the excavation, of the equilibrium of the strains or pressures holding everything fast and firmly together—the removal of the support thereby causing the rocks to get relief and to fly off or apparently to explode."*

In the gneiss quarry at Monson,† Mass., the strike is N. 10° E., and the dip W. 10° N., at an angle of 80°; but the only divisional planes consist of a set of parallel joints, separating the rock into beds which are nearly horizontal or dip about 10° to the west, nearly parallel to the general

* W. S. Gresley, R.E., "Explosive Slickensides," *Geol. Mag.* (1887), 522.

† W. H. Niles, "Some Interesting Phenomena Observed in Quarrying," Proc. Boston Soc. Nat. Hist., XIV (1870-71), 80-86; and, "On Some Expansions, Movements and Fractures of Rocks, Observed at Monson, Mass.," Proc. Am. Ass. Adv. Sci., XXII (1873), B, 156-163.

surface of the hill, and vary in thickness from a few inches to several feet. During the quarrying by splitting off stone, by wedges, parallel with the strike, whenever a stone of considerable length is thus separated from any entirely undisturbed portion of a bed, it is found that the stone expands lengthwise, as indicated by the movement of the drill-holes on the side near its freed end. These movements may be either uphill or down, but they are always in northerly or southerly directions, with the strike of the rock; no traces of expansion in easterly or westerly directions have been ever seen; they have occurred during all conditions of the weather, warm and cold, wet and dry. In one mass of rock, 354 feet long, 11 feet wide and 3 feet thick, the amount of expansion after dislodgment was $1\frac{1}{2}$ inches up the slope of the hill. When the fracture by wedging is suddenly and thoroughly made, the expansion takes place immediately, and sometimes the expansive force itself completes the desired work, the stone suddenly springing into the elongated state. Spontaneous fractures also occur, of which one was fully 4 inches wide. On removal of overlying beds, spontaneous upward bendings and swellings of the lower beds also occur, most frequently in the thinner sheets, up to 4 feet in thickness, with formation of miniature anticlinals. The amount of elevation varies from $\frac{1}{4}$ inch to 3 or 4 inches, even in a single afternoon. The span of the arch thus formed is sometimes 50 feet, while some are only 3 feet broad; the crests always trend in easterly and westerly directions, are sometimes ruptured, and are evidently caused by expansive thrust in northerly and southerly directions, since the edge of the sheet at each base of the anticlinal arch remains so closely attached to the underlying bed that no lateral slipping of this edge upon the rock could possibly have taken place. In one arch, which measured nearly 60 feet from base to base, of a bed 10 to 16 inches in thickness, the stone was found to have stretched at that time more than $\frac{1}{1000}$ of its original length.*

* W. H. Niles, "The Geological Agency of Lateral Pressure Exhibited by Certain Movements of Rocks," Proc. Boston Soc. Nat. Hist., XVIII (1875-76), 283.

Another result of this rock expansion is the formation of numerous cracks and fissures, by which in one case 10,000 tons of rock were moved. These are commonly formed slowly, but sometimes suddenly, attended by the shattering and crushing of solid rock, loud reports, cracking and explosions, and the hurling of stones of considerable size for a short distance and to a height of several feet.

In a quarry of gneiss at Waterford,* Conn., slight movements of the rock have been observed under the following conditions: In using the steam-drill for cutting out blocks of stone from the rock in place, if the holes are made very near each other, the small portions of stone thus left between them are often crushed, and the drill so pinched that it cannot be worked. The pressure is limited in its action to a northeasterly and southwesterly direction. The quarry is located a little east of south from Monson, at a distance of nearly 60 miles in a direct course. The stone quarried there, commercially known as Millstone Point Granite, is a gneiss, which, although differing somewhat in external appearance from the Monson stone, is of similar constitution and texture, and occurs under similar geological conditions.

In the town of Groton,* Conn., evidences of pressure were observed upon some thin sheets at the bottom of one of the small quarries.

The phenomena above briefly described were found to be independent of conditions of temperature or moisture, being observed at all seasons of the year and during all kinds of weather. The direction and intensity of the movements showed that they could not have been produced by vertical pressure, such as the weight of adjacent overlying rock and loose materials. It has been pointed out by Mr. Niles that their northerly and southerly direction is identical with that of the pressure established at the close of the Tertiary Age which caused the changes of level in the northern part of the continent during the Quaternary Age, as well as with that of recent changes of level of the Atlantic coast.

At New York City, some years ago, during excavation of

*W. H. Niles, "The Geological Agency," etc., 279.

a tunnel under the East River, many blocks of gneiss were observed from time to time to start from their places with almost explosive violence.* Similar observations have been often made in the granite quarries at Westerley, R. I., in Southwestern Virginia and elsewhere. In those at Barre, Vt., I am informed that holes and grooves, cut during drilling and channeling, have been found gradually closing up in a mysterious way, though the observer was not certain whether this was due to expansion of the surrounding work or to its gradual sliding down a gently inclined bedding-plane.

In sedimentary rocks, also, evidences of tensile or compressive strain have been frequently observed. For example, at Wilmot's flagstone quarry, on Basket Creek, N. Y., the quarrymen removed the top, one day, from a ledge of rock extending back about 11 feet, and began raising the lifts of flagstone (a rock similar to that shown in *Fig. 6*): "The ledge is only some 7 or 8 feet high and over 40 long. After a few top-layers of stone had been taken off, it was noticed that the lifts under them began to rise in spots, and in a short time would rise up clear across the ledge, much in the same way as flooring will occasionally become so swollen as to bulge up at some point in the shape of the roof of a house. This was at first ascribed to the heat, as it was in the afternoon, and the sun shone in very hot upon the ledge; but as fast as one lift was taken off, the one below would begin to rise in the middle, as though, being wedged or sprung in at the ends, they rose in the middle as soon as the weight was off. The lower in the ledge the men got the stronger seemed to be the impelling force; and on Friday the men found, on going to work in the morning while it was cool, that during the night an immense course

* "This is a gray gneiss much like that at the north end of Seventh Avenue and near One-Hundred-and-Fiftieth Street. At one place, 150 to 250 feet east of the west shore of the (Blackwell's) island, it proved to be under great strain, so that from time to time, even six months after the tunnel was opened, it cracked with reports like a pistol-shot, and at intervals masses fell from the roof."—J. F. Kemp, "The Geological Section of the East River at Seventieth Street, New York," Trans. N. Y. Acad. Sci., XIV (1895), 275.

of stone had risen in the center of the ledge, extending across the 11 feet to a height of 7 inches, and sloping like the roof of a house each way to the ends of the ledge."

In the sandstone quarries at Portland,* Conn., the beds dip about 12° or 15° to the southeast, and had been excavated to a depth of 140 feet below the original level of the soil. At the bottom of this cavity a channel, 1 foot or more in width and some 50 or 80 feet in length, was rapidly sunk by several workmen with their picks, in an east and west direction. The stratum had been found to be about 6 or 7 feet in thickness, and "when the channel had been sunk to within about 9 or 12 inches of the bottom of the stratum, suddenly the remaining stone at the bottom was crushed to fragments with a loud report by an enormous lateral pressure, and the men in alarm leaped from the excavation they had made. By examination it was found that the walls of the groove or canal just made had approached each other about $\frac{3}{4}$ of an inch, the stratum through which they had cut having on one side slidden this distance in its ancient bed." This has repeatedly happened in channels excavated in a new stratum in an east and west direction, at or near the bottom of the quarry, and but in slight degree in channels cut north and south.

In the sandstone quarries at Berea,† O., the beds are of different thicknesses and are nearly horizontal in position. An important part of the work of quarrying is the cutting of trenches in the beds, which are just wide enough for the men to work in. Where the quarries are well opened, these are usually cut perpendicularly into the working face, *i. e.*, east and west, where the faces commonly run north and south. It has been found that on approaching the lower surface of a bed with a long cutting, the stone remaining at the bottom of the channel has been broken or crushed, and portions of the stone desired for use have been so fractured as to be rendered worthless. For this reason the trenches are cut

*J. Johnston, "Notice of Some Spontaneous Movements Occasionally Observed in the Sandstone Strata in one of the Quarries at Portland, Conn.," Proc. Am. Ass. Adv. Sci., VIII (1853–54), 283–6.

† W. H. Niles, "The Geological Agency," etc., 273.

through in short horizontal sections to the bottom of the bed. Even with this care, sudden lateral slippings of the stone have frequently taken place, especially when the channels were nearly completed. These have usually been attended by cracking and explosive sounds, and sometimes the movements have been of such violence as to throw pieces of stone from the surface, or to crush portions of the rock into small fragments. In these instances it has been found that the portion of the bed which has moved has also permanently expanded, so as to narrow the channel perceptibly. There have been instances in which the expanding rock has not only closed the channel, but has also pressed against the stone which was upon the opposite side of the trench with such force that it has been broken. On one occasion the edge of the expanded portion of a bed was observed thrust over the other edge, so as to bring one portion vertically above another part of the same bed, which was originally some 15 inches or more from it horizontally. If, now, another channel be cut in such a bed, parallel with the first, but at some distance back into the face, there will be either no apparent movement of the rock or it will be much less than that which followed the cutting of the first channel, showing that the force has been partly or wholly expended. The movements are greatest and most energetic in a northerly and southerly direction, but comparatively small where north and south channels have been cut.

In the quarries of "Athens marble" at Lemont,* Ill., the pot-holes occurring in the water-worn surfaces of the upper layers of the limestone, when of sufficient depth to penetrate one layer and enter another, are occasionally found to be dislocated—that is, one layer has slipped upon the other, so that the upper and lower portions of the pot-hole are in some cases entirely separated from each other. The dip is hardly perceptible, not more than 1° or 2° to the southeast. A similar dislocation of drill-holes was observed and was a clear evidence of lateral sliding, for the parts of the drill-holes remaining upon the edge of an upper layer were

* W. H. Niles, "The Geological Agency," etc., 277.

not vertically above the lower parts of the same holes shown upon the edge of the under bed. In one quarry, also, there was an elevation of a part of the bed forming the floor. It was an anticlinal axis of more than 800 feet in length, and its trend was nearly east and west. In its most conspicuous part the elevation was from 6 to 8 inches, and the arch measured from 16 to 18 feet from base to base over the crest. It was formed along the line of a vertical joint, which extended beyond the limits of the quarry. The contiguous edges of the bed were bent upward, making an elevation which was a little more upon the north side of the joint than upon the south, and a slight fault was in this way produced.

The testimony of earthquakes is beyond question, to the sudden yielding and slipping of strata, in response to accumulating strain at certain points. Such phenomena are common not only in volcanic districts, but in regions of crystalline rocks where other evidences of compression have been observed. In the lower Connecticut Valley, such disturbances have been accompanied by both jarring and sounds, the mysterious "Moodus noises," early known to the Indians, and heard by the first colonists from 1709 to 1729; they again occurred in 1852 and 1885. Still more recently, in 1897, "there was a sound like a clap of thunder, followed for some two hours by a roar like the echoes of a distant cataract. A day later, there was a crashing sound like heavy muffled thunder and a roar not unlike the wind in a tempest. The ground was shaken, causing houses to tremble and crockery to rattle 'as though in an earthquake.'"

It might reasonably be presumed that rock-strains, of sufficient intensity to have produced such remarkable phenomena to the eye and ear, must have also generated abundant internal evidences of stress, on a minute scale, throughout the material of stone. Under the microscope, these "strain-phenomena" form the subject of constant observation by the petrographer; the same cracking, stretching and flattening of crystals and nodules; the bending, crumpling, twisting and splitting of mica-plates; the "strain-

shadows" in quartz-grains, and optical anomalies, caused by still active pressure in garnet, leucite, haüyne, etc.; the parallel sheets or bands of fluid-cavities or fissure-inclusions,* in quartz (*Fig. 15*), crossing through adjoining tongues of feldspar, fractured blades of fibrolite, etc., and marking the directions of shearing-strain; the secondary lamellar twinning and gliding-planes in plagioclase-feldspar and calcite (indicated by the parallel stripes, *Fig. 17*); the schiller structure in hypersthene; and the so-called "cataclastic" structures, represented by the cracking and crushing of grains into friction-breccia, into sand-grains surrounded by fine particles (mortar-structure), and even to a finely granular uniform mass ("mylonite"), in which all original forms have been ground down and obliterated.

The coincidence of solution-planes in a mineral (*i. e.*, those of most ready yielding to chemical action) with certain crystallographic faces, twinning-seams and the gliding-planes developed by shearing-strains, suggests the connection of such stresses with directions of easiest attack by weathering agencies within the material of building-stones. For these peculiarities of structure characterize minerals which predominate in the constitution of stones used for building, viz., the feldspars, calcite, dolomite, etc.; and they call for more thorough investigation in application to the needs of the builder.

Sorby† has long ago shown, in connection with metamorphism of rocks, the effect of pressure in increasing the solubility and rapidity of removal of certain minerals, especially calcite, and the subject has been later discussed by Van Hise. It may therefore be possible that the detection of abundant "strain-shadows" or other evidences of the presence of active stress among the grains of a rock may be safely taken as evidence of its ready tendency to attack and disintegration by atmospheric waters and of its unfitness as a durable building-stone.

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*A. A. Julien, "On the Fissure-Inclusions in the Fibrolitic Gneiss of New Rochelle, N. Y.," *Am. Quart. Micr. Jour.* (1879), 1–15.

†H. C. Sorby, *Quart. Jour. Geol. Soc.*, XXXV (1879), 88.

Some measure of the intensity of these stresses, as estimated from the thickness and weight of the superincumbent strata required to produce them in particular instances, has been deduced by certain investigators from the contents of microscopic fluid-cavities. These abound in the quartz-grains of granites and gneisses, often to the amount of 1,000 millions to the cubic inch, equivalent to 1 per cent. of the volume of the quartz. They are shown in the quartz-grains in granites (*Figs. 2* and *15*), and still more plainly in that of Fox Island, Me. They may be partly filled with water, brine, or often liquid carbonic acid with floating bubble of gas. The condensation of the last substance as a liquid, at 32° C., requires a pressure of 38½ atmospheres, or over 600 pounds to the square inch. The intensity of pressure and the temperature prevailing at the time of consolidation of the rock have been the object of observations and experiments by Profs. H. C. Sorby and W. N. Hartley. The floating bubble in a cavity was held to represent the vapor-filled vacuity, left on contraction by cooling of the liquid which originally filled the whole cavity. By determination of the temperature at which the liquid could be compelled artificially to resume its original volume in selected tubular cavities, it was estimated that, in granites of the Scotch Highlands, the rock had been consolidated under pressures of about 69,000 to 76,000 feet of rock at temperatures between 200° and 360° C., a dull red heat.

The amount of strain now remaining in such a granite may be inferred from the fact that its liquid contents often reach as much as $\frac{1}{10}$ or $\frac{2}{10}$ of 1 per cent. of its weight, *i. e.*, 3 or 4 pounds of liquid under intense compression to a ton of the rock.

A natural corollary from these views is that the constructor, in the selection of stone, should give preference, other things being equal, to material from beds whose geological position (*e. g.*, in the "neutral plane" of a flexure) and whose texture imply the absence of serious tension, *e. g.*, dense sandstones from horizontal strata, limestones presenting few crevices and veinlets, and probably granites whose quartz-grains are poorest in liquid inclusions.

In regard to the recrystallized limestones, the marbles, it has been pointed out by Van Hise,* that calcareous sediments, after a dynamic movement has ceased, show a marked tendency to recrystallization in presence of warm solutions and under static conditions; and that the particles recover from a state of strain in the progress of this rearrangement, so that the calcite-grains usually show little or no strain effects. In massive marbles we may therefore have little fear of danger from remnants of active tension.

(3) *Strains Caused by Present Physical Conditions.*—We have still to consider certain physical conditions to which stone is subjected by which abnormal strains are produced, aside from artificial strains developed within masonry during construction.

By changes of temperature caused by vicissitudes of climate, it is evident great variations of tension must be generated in masses of stone, not only between its superficial and deeper-lying portions, but also still more variant between its component mineral-grains. The latter are due to the difference in amount of expansion by heat of the various kinds of minerals,† *e. g.*, the coefficient of cubical expansion for quartz (0·000036) is over twice that of orthoclase feldspar (0·000017); also to the difference in degree of linear expansion within each mineral in the directions of its crystallographic axes, *e. g.*, varying in the axes of a common form of feldspar, adularia, as 659:2914:15687, or as about 1 to 4·4 to 23·8. In other words, the grains of one of the most common constituents of rocks expand over four times as much in one direction as in another, and nearly twenty-four times as much in a third direction!

The efficiency for harm in such enormous variations must depend chiefly, it may be presumed, on sudden increments to tensions already existing and on consequent sudden developments of energy and movement within the stone. Thus occur, in extreme cases, violent expansions of rock on

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* "Principles," etc., 703, 707, 771.

† F. W. Clarke, "The Constants of Nature," Smithson. Misc. Coll., XIV.

arid plains and in torrid regions, under thermal variations which may reach even 100° F. or more in a single day. For example, in the Trans-Pecos region of Texas, where diurnal variations of temperature amounted to 60° to 75° F., Streeruwitz heard, on the heights of the Quitman Mountains, peculiar crackling noises and occasional loud reports, caused by the scaling off from the solid rock of broad flakes up to 4 inches in thickness, and by the splitting of huge boulders under the heat of the sun.

Similar changes of stresses and movements also occur among and within the blocks of stone in masonry exposed to the sun and weather, under ordinary daily temperature-variations. An interesting example of these has been recently reported to me in regard to a five-story building in Warren, Pa. Its solid ashlar front, facing westward, is constructed of the purple-brown Hummellstown sandstone, in blocks commonly 2 feet in height, 1½ feet in thickness, and from 3 to 8 feet in length. These are now found to be, in many cases, fractured completely across, the crevices opening 2 or 3 millimeters during the day and closing at night. These fractures and movements, apparently caused by alternations in special absorption of heat and expansion by the dark stone and in its nightly radiation and contraction, indicate a constant increase and release of tension among its grains—their constant swing to and fro under the daily changes of stress—their failure to recover their exact original positions, and a constantly increasing divergence of certain masses of the stone. In experiments of the U. S. Engineers at the Watertown Arsenal, it was found that bars of stone, 20 inches long, after being heated 180° and again cooled to the starting-point, 32° F., still retained a slight expansion, "permanent swelling," which amounted, in several granites, to 0·004 inch; in marbles, 0·009 inch; limestones, 0·007 inch; and sandstones, 0·0047 inch. Observations on masses of stone like those above stated at Warren seem to show that such permanent swelling increases, by frequent repetition of alter-

nations of temperature, to a degree which may seriously injure and even endanger its cohesion.*

When exposed directly to flame, during burning of buildings, the expansion and stress may become so great as to produce violent explosions, especially of granite, where the bursting of fluid-cavities in quartz may be also involved. The fire-tests hitherto recorded, to determine the resistance of varieties of stone to such violent changes of temperature, are confined to a very few series, comprising but a limited number of kinds, and without the uniformity of method desirable for safe comparison of results. Even at ordinary temperature-variations in the atmosphere, expansions and contractions of notable amount occur, sufficient to embarrass or defeat the builder in constructing water-tight joints in coping of walls, flagging over vaults, casemates and tunnels, etc.

Strains result also from processes of chemical action progressing within stone, such as absorption of water, oxygen and carbonic acid, with enormous expansions in volume. The oxidation and decay of iron sulphides, I have elsewhere shown,† depends, to any degree of practical importance to the builder, not only on the intimate molecular inter-

* This process has been recently well described in detail by G. P. Merrill: "The mass of stone is made up of an admixture of mineral particles without definite order of arrangement, and all practically in actual contact with one another. As the temperatures rise, each mineral expands ever so slightly and crowds against its neighbor; but aside from the unequal expansion of minerals of different species, the process is further complicated by their tendency to expand unequally along their different crystallographic axes. So all through that portion of the stone thus warmed there arises a condition of very unequal tension, which is naturally greater the greater the amount of heat. As temperatures fall, a corresponding contraction takes place; but in material so granular and inelastic as stone, the particles do not again recover exactly their original relative positions. Minute rifts are opened, not merely between the granules, but also along the cleavage-planes of the minerals themselves, so that in time all cohesion is lost and the stone becomes so weak as to fall away to the condition of sand, or, as is more commonly the case, absorbs so large an amount of water that, when freezing ensues, disintegration results."—Rep. Maryland Geol. Survey, Vol. II, 1898, p. 92.

† "Pyrites in Building-Stone," Ann. N. Y. Acad. Sci., IV (1887), 216-223. See, also, paper of A. P. Brown, Proc. Am. Phil. Soc., XXXIII (1894).

mixture of marcasite, but the very amount of this can be predetermined in crystals of pyrite which appear to be pure. The softening of micas and kaolinic decay of feldspars, however, are the most deleterious agencies of this kind. With accompanying aid of antecedent latent tensions, and those developed by heat of the sun by day, chilling contraction by cold rainfalls and by night radiation, and the final rending strain of enclosed water-films solidified by frost, it is not surprising to find the exterior of a strong stone exfoliating in plates and concentric crusts.

It is the multiplication of all these stresses, though often individually minute, the accumulation of these apparent trifles in tension, which seems to account largely for the anomalies constantly observed in the resistance of stones to crushing and other mechanical strain, and for the variations in their endurance of atmospheric attack. With the nature and degree of such latent strains once comprehended, tested and provided for, a builder need no longer be mortified, in handling a stone of known high crushing strength, to find it subject to sudden and apparently capricious fractures—in ashlar, pillars, or sills, it may be—even at low amounts of actual compression, well within the accepted limit of security. At least, such occurrences should be ultimately confined to the shearing-stresses produced under conditions of insufficient support, such as imperfect adaptation of hewn blocks, lack of mortar, or yielding foundations.

[*To be Concluded.*]

CHEMICAL SECTION.

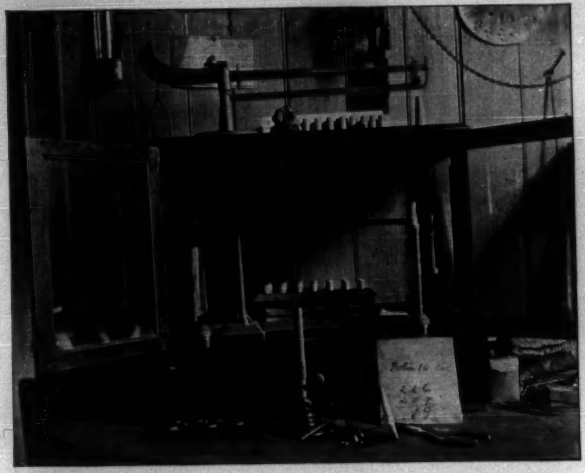
Stated Meeting, February 21, 1899.

QUICK TESTING OF LEAD-TIN AND LEAD-ANTIMONY ALLOYS.

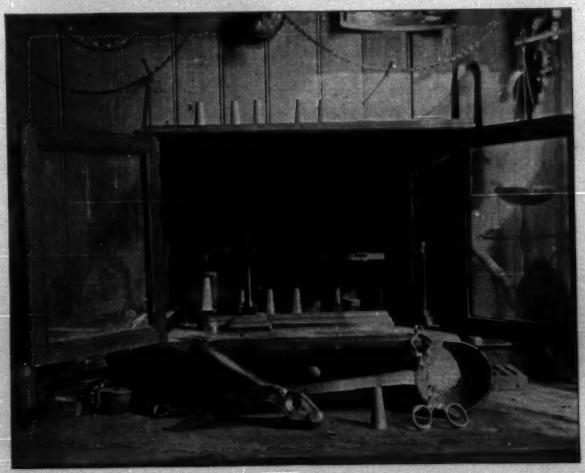
By JOSEPH RICHARDS,
Member of the Institute.

While great strides have been made in analytical chemistry, yet there is in the direction of quick work a field for the chemist that needs urgent attention, and as far as he has been able to meet this demand the metallurgist is benefited by the progress made and the results attained. I allude to methods of quick determinations, approximately true and sufficiently so for the purpose required.

My own experience for the past thirty years has been confined almost exclusively to the working of the white metals, such as lead, tin, antimony, aluminum and zinc. It is well known that the bulk of the lead ores are contaminated with antimony, and in the refining of lead, the antimony when at a dull red heat is rapidly oxidized and floats on the top of the molten metal as a scum, carrying particles of lead with it. This is removed as fast as formed, and in the course of ten to forty-eight hours all the antimony is eliminated. It is very desirable in this process that the workman should know how he is progressing in his work; and in order to meet this demand I have made a series of tests of the relative weights of standard alloys of antimony and lead, from pure lead up to 24 per cent. of antimony. At this point the lead is saturated, and if more than that quantity of antimony is present it will float on the top of the molten mass; so that a standard alloy of 24 per cent. of antimony is the highest that can be tested by my apparatus. I made castings of these alloys in a mould, took the average weight of 10 of each grade, and the machine was marked to exactly balance at the line or weight given by the average test. This I continued from pure lead up to 24 per cent. anti-



MACHINE FOR TESTING TIN PLATE.



BALANCE FOR TESTING TIN-LEAD ALLOYS.

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COLLEGE
LIBRARY.

mony; thus a quick and reliable means is at hand, so that all the workman has to do is to carefully cast his bullet, place it on the balance, and it shows him at once the amount of antimony in the mixture. The following difficulty here arose: while antimony is lighter than lead, if a small amount of antimony is present (less than 2 per cent.), instead of making the bullet lighter, it is heavier than pure lead, and it is not until over 2 per cent. is present that its weight becomes less than that of lead. This difficulty I overcame by discovering that the physical properties of these alloys is such that if a small button is poured on a flat plate and allowed to cool, the surface is not at all like lead, but of a fine white crystalline appearance. So I have supplemented my test machine with a set of buttons of a known composition from 2 per cent. down to zero, changing composition by $\frac{1}{10}$ per cent. in each button. I made the first button 2 per cent., the next $1\frac{9}{10}$ and so on down to pure lead.

Thus the operator can go on with his work until there is a perfectly lustrous surface, free from frost, and at this point the lead will be 998 fine or over. The practical value of these tests is shown by the fact that since I made the first machine for the National Lead Company their order has been duplicated six times.

Another method of quick testing was needed for the alloys of lead and tin. When I commenced this business the only way I could find out the percentage of tin in solder, solder joints, pewter and such like metals, of which we were buying hundreds of tons each year, was by chemical analysis, and I found this took several hours and required great care and much practice to get accurate results. The use of the specific gravity test was suggested to the writer by an old member of the Institute, Mr. G. H. Perkins, but the means employed were crude and unsatisfactory. So I again commenced with pure lead as a standard, taking 99 of lead to 1 of tin, and so on till I got up to pure tin. I made over 2,000 tests, confirmed them by analyses of the metals used, and so made a set of standard weights, from which standards the scale now before you was marked; each mark being the average of about twenty tests, and is correct

to the tenth of 1 per cent. I may here remark that the weight of these alloy bullets is, for some physical reason, different from the calculated specific gravities of the alloys, some being heavier and some lighter than the calculated weights. The machine before you has a graded beam, and the moulds are all made to an exact standard and are all interchangeable. If a firm loses or breaks a part of the machine, it can be easily replaced or a new mould procured. So that now, when we melt alloys of tin and lead, we do not even have to depend on accurate weighing of the metals to be melted, but test each pot and can check any error that the workman might have made in his weighing. So accurate is this test that a difference of a quarter of 1 per cent. is easily detected, and my experience in my own laboratory and with samples sent to a number of good chemists, is that I would every time prefer my test for practical purposes to that of the ordinary chemical laboratory.

When we consider that many thousands of tons, roughly estimated at 75,000 of solder alone, are used in the arts every year, one may easily perceive how valuable a factor to the trade such a machine as this becomes, and it has been so recognized, for at this time at least nine-tenths of all the smelting and refining works in the United States are using my machine. Also in the new industry of manufacturing roofing-plates with tin and lead alloy coating, called terne plates, I find that I have supplied three-fourths of the plants with these machines; so that they may test and keep regular the proper percentage of tin and lead in their bath. Many large purchasers of solder find such a testing machine indispensable to protect themselves from lower grade metals than they pay for. This simple, accurate and altogether satisfactory method of testing is therefore now in common use.

In my machine for testing roofing-plates, the beam is so adjusted that if a piece of the sample plate exactly cut to template size and then weighed on the scale, gives the weight of a box of 20 x 28 plates in pounds. For instance, if the plate cut shows a weight of 220 pounds, that is the weight a box of plate would be with the coating on it. This

piece of plate is then heated over a Bunsen burner till the coating melts, then wiped clean, heated again and wiped till no more metal is on the surface. When the surface is blue all over, showing that all the coating is removed, weigh it again. If it now weighs 200 pounds, this will be the weight of the black plate per box and the difference between the two weighings is the weight of the coating in pounds.

NOTES AND COMMENTS.

THE SMOKE NUISANCE IN PARIS.

Notwithstanding the general impression that Paris is a notably clean city, the growth of the smoke nuisance has forced the municipal authorities to take measures for its regulation by legislation. Before proceeding to do this, however, they appointed, in 1894, a technical commission to investigate the subject. This body has lately completed its labors and has published a report embodying its results and recommendations, an abstract of which is herewith taken from *Engineering Magazine*.

The commissioners instituted a series of tests with the view of determining what were the best attainable smoke-preventing devices, and offered prizes to the furnaces demonstrating the best results.

The outcome of this procedure was the entering for competition of no less than 110 smoke-preventing appliances, which may be classified as follows:

(1) Mechanical stoking and uniform combustion	16
(2) Supplementary injection of hot or cold air	20
(3) Injection of steam with or without addition of air	5
(4) Mingling of flames and combustion of smoke	7
(5) Gas producers and gas firing	7
(6) Pulverizing the fuel previous to combustion	2
(7) Washing of the discharge gases	16
(8) Miscellaneous systems	37

The following information relates to the manner of making the tests:

"The various devices were successively erected under the same boiler * * * and the same fuel was used in all the tests. The fuel was the Anzin briquette, of the ordinary quality, containing an average of 8·17 per cent. of ash, and 17·84 per cent. of volatile matter. Each device was subjected to two kinds of tests, one with slow firing, and the other with the firing forced to supply the engines fed by the boiler to their full capacity. Each test was made twice, the first time with a stoker selected by the maker of the device, and the second with the stoker employed by the commission, thus eliminating as much as possible the personal equation. * * * The tests included the determination of the quantity of fuel burned per unit of grate area, and

the evaporation per unit of area of heating surface and per unit of weight of fuel, as well as the measurement of the relative amount of smoke produced.

"The measurement of the amount of smoke produced by each device was accomplished by an ingenious method, which, while probably hardly entitled to be considered as a method of precision, was still reasonably correct, and doubtless fair to all the devices tested.

"A smoke scale of five degrees of intensity, ranging from complete absence (of smoke) to complete opacity, was decided upon, and the amount produced was recorded upon cylinders revolved by clockwork, by means of a pencil which could be pressed into contact with the paper by hand. The observer, watching the chimney top, pressed the pencil against the paper during any period when smoke was produced, the paper being divided into five portions corresponding to the five grades of smoke."

So much for the method of the tests. The conclusions, which are of general applicability to all cities where the smoke problem is a live question, will be read with interest:

"In the first place, the experiments made before any of the special devices were tried, showed that the ordinary grate is unsuited for smokeless combustion, and that, even with the most careful stoking, the common grate will permit the formation of smoke.

"In the second place, it was clearly demonstrated that smoke prevention and economy do not necessarily go together. The blackest of smoke represents an insignificant amount of fuel, and the tests demonstrated that the devices which produced the least smoke were not the most economical. It should, therefore, always be assumed that the prevention of smoke involves expense, proper allowance being made therefor.

"Smoke may always be prevented by using coke, but as this is in many cases unavailable, the only remedy lies in the use of such devices as will produce a minimum of smoke, the true principle being, not the combustion of smoke, but the absence of its production.

"The commission recommended the prohibition of dense black smoke, as the trials showed that many devices would accomplish this result. It was also recommended that those devices which showed the best results during the tests be placed in manufacturing establishments with the view of establishing their durability and effectiveness in regular service, and, above all, that the existing regulations be thoroughly enforced by patient and competent officials."

W.

RENDERING CALCIUM CARBIDE STABLE IN THE AIR.

Calcium carbide, as is well-known, rapidly disintegrates when exposed to the air, through the action of the moisture therein contained; hence, it is necessary to preserve it in hermetically-sealed vessels until it is required for use.

In a recent English patent, the inventor proposes to obviate this difficulty by "saturating the carbide with liquid hydro-carbons, as for instance, petroleum." By this process, the carbide, immediately after the usual crushing operation, as it comes from the furnace, and which, still at a temperature of 212° to 250° F., is conveyed to a bath of petroleum residues, where it remains

about five or ten minutes. It is then withdrawn and allowed to drain. When thus treated, it is said that the carbide is not affected by atmospheric moisture, whereas with a body of water it decomposes very slowly at first, but with increasing rapidity "as the particles are laid bare." W.

ARTIFICIAL AND NATURAL INDIGO.

The commercial production of artificial indigo by the Badische Anilin u. Soda Fabrik, has aroused the greatest interest in the textile world, and has caused much attention to be devoted by chemists to the composition and properties of the natural product.

It has been shown that natural indigo constantly contains, besides indigotin and mineral matters, indirubin, indigo-brown, and indigo-gluten.

As the synthetical indigo is pure indigotin, it is a matter of some importance to determine whether the other incidental constituents of the natural product possess properties of value in dyeing, in order to ascertain the comparative value of the two products.

The results of the exhaustive study of the natural product by MM. Schwarzenberg and Schwartz appear to establish the following facts of value.

(1) The greater part of the indigo-gluten passes into solution in the indigo vat; a small quantity remains in the vat—sediment. This constituent of the natural product is without influence in dyeing.

(2) Indigo-brown forms an insoluble compound with lime and remains in the sediment. This constituent, also, has no effect on indigo dyeing.

(3) Indirubin dyes, to some extent, but it increases neither the fastness nor the brilliancy of shade of the dye; the effect, indeed, of a large proportion of it, is to give a shade which is dull and unpleasing.

These conclusions, it is stated, have recently been fully confirmed by the Badische Anilin u. Soda Fabrik. These manufacturers declare, also, that the fastness to rubbing and washing of their new artificial indigotin, when dyed on cotton fabrics in the ordinary manner, is equal if not slightly superior, to that of natural indigo. They state, also, that the shade and fastness of indigo dyes are not influenced by indirubin, indigo-gluten, and other organic substances present in indigo, but that such modifications as may occur in these features are due to methods of setting and working the vats.

It will be of interest to notice, in conclusion, that the manufacturers above-named, state that they are in a position to produce, by a synthetical process, indirubin. W.

DAMAGE TO IRON VESSELS BY GALVANIC ACTION AT A DISTANCE.

An unusual and interesting case of galvanic action exerted at a distance is reported from an Italian source.

The captain of the port of Leghorn brought action in court against the owners of certain wooden yachts with coppered bottoms to compel them to remove their vessels from the neighborhood of a number of new war-ships and other vessels with iron or steel hulls lying in the same part of the harbor.

The *London Engineer* is authority for the statement that the iron vessels were damaged by galvanic currents set up from the copper bottoms of the wooden yachts. The fact of the damage to steel and iron ships having taken place and of its being due to this cause was clearly established before the court, and as a consequence the captain's order for the removal of the copper-bottomed wooden yachts from the Darsena harbor of Leghorn was supported by decree of the court.

The article proceeds to explain that the galvanic contact in this case was established by the ropes which were made fast to different buoys in the basin, but this explanation is quite unnecessary, as the sea water forms a sufficiently good electrolytic conductor. W.

LIQUID FLUORINE.

Messrs. Moissan and Dewar have succeeded in liquefying this element, and publish some interesting facts respecting the liquid. Thus, its boiling-point was ascertained to be about 187° (Centigrade) below zero, and at 210° below zero, it showed no signs of solidifying.

If air be admitted to the liquid it is instantly liquefied, producing in the tube two layers—the upper one colorless, of larger size; the lower one, of a pale-yellow, being fluorine.

In order to determine the density of the liquid, substances of known density were immersed in it after first being sufficiently cooled. It was found that wood, caoutchouc and ebonite floated on the liquid, while amber remained suspended. The density was thus determined to be about 1·14.

The intense activity of fluorine was strikingly shown by the circumstance that, even at the extremely low temperature of 210° (C.) below zero, hydrogen instantly combines with it with the production of great heat and light. Oil of turpentine explodes, when brought in contact with it, with a separation of carbon. A bottle of the liquid was accidentally spilled on the floor, when the wood caught fire. W.

ACETYLENE AS A POWER GENERATOR.

The recent annual meeting of the German Society of Gas and Water Experts in Nüremberg, was made the occasion for an exhibition of acetylene and its applications.

In reference to the application of this interesting product to the gas engine as a power generator, *Dingler's Polytechnisches Journal* has the following comments that will be read with interest by American engineers, to most of whom such application will doubtless be new:

The principal difficulty hitherto encountered in applying acetylene as a motive-power lay in obtaining a non-luminous flame—the evidence of complete combustion—without danger. This difficulty, our authority declares, is now overcome by the devices constructed by one of the Berlin acetylene companies.

It is stated, in the same connection, that acetylene is now applied in power generators (gas-engines) in the same manner as ordinary coal-gas and water-gas. In order to obtain the full output of the energy of the gas, it must be

mixed with air in the right proportion to produce perfect combustion, which is indicated by a non-luminous flame. The power developed by the explosion of acetylene completely burned in the cylinder is said to be much greater than that obtainable with water-gas. W.

ELECTRICITY IN PAPER-MAKING.

The *Electrical World* reports that the Cumberland Mills, near Portland, Me., are operated by power electrically transmitted from a waterfall four miles distant.

The generating plant consists of two 300 horse-power dynamos coupled to 48-inch Victor vertical turbine. The alternating current system is used, the pressure being raised by transformers from 1,100 volts at the generators to 8,000 volts at the mills, where it is again reduced to 400 volts for supplying the motors.

The efficiency of the plant is found to be about 76 per cent., from the brake horse-power of the turbines to that of the motors. A marked saving is said to be effected in comparison with steam-power. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 19, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 145 members and visitors.

Additions to membership since last report, 60.

The president made reference to the highly gratifying increase in the membership since the beginning of the present year, and urged the members to second the active efforts of the Committee on Membership.

Mr. A. E. Outerbridge, Jr., presented an interesting address entitled, "Notes of a Trip to the West Indies." The speaker gave an account of his observations made during a recent trip of several weeks to a number of these islands, with special reference to their industrial conditions. The subject was profusely illustrated with the aid of the stereopticon.

Mr. John Jerome Deery read a paper describing the "Improved Methods for the Purification of Sewage and Water," as exhibited by the operation of the municipal plant at Reading, Pa. The speaker described this important installation in detail, illustrating the same with lantern views. The subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. John Forbes described and illustrated in operation several modifications of an improved "Apparatus for Sterilizing Water," by which it was claimed to be practicable to sterilize from 2,000 to 5,000 pounds of water by the expenditure of 1 pound of coal. The subject was likewise referred to the Committee on Science and the Arts.

Adjourned. WM. H. WAHL, *Secretary.*

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1898–1899.

The number of students this year has been 26 per cent. greater than last year, showing what a good indication the school gives of the condition and prospects of the mechanical interests of the city. Very few come to this kind of a school who do not possess mechanical instincts which they desire to develop. They are either connected with some industry or desire to be, or they would not make the sacrifice necessary to learn this very important requisite. This feeling is a most promising thing for the country. The value of it was forcibly shown in the recent war with Spain, particularly in the naval engagements, where the forethought, care and mechanical knowledge and instincts of our officers and men won such signal victories over the intrigues, diplomacies and vanities of the Spaniards. It is to be hoped that this condition will continue and increase, and that the great majority of our youth will be interested in physics, mathematics and mechanics, so that when emergencies arise they will be powerful to meet them. All institutions that tend to develop this condition should be fostered and encouraged, and young men should understand that, in whatever position circumstances and fortune have placed them, they should not neglect to cultivate, to some degree at least, a knowledge of mechanics and the laws which govern material things. My experience in teaching in this school has clearly shown me the great difference in human natures in this regard. The experience, associations and inheritance of one student has so influenced his mind that he can quickly and clearly conceive of the relations of lines, surfaces and solids in the abstract, while another student, with different gifts has great difficulty in understanding them even in the concrete. But time, thought and training almost always overcome this difference to a great extent, and in many instances the improvement has been something remarkable, the most unpromising cases at the beginning ranking among the best at the end. This has often proved to me the wisdom of the system of individual instruction that we use, modifying the course and the speed to suit the character of each case. Of course, many enter the school who have not the quality of mind, the instincts or the patience to ever take sufficient interest to profit by it, but most of these go no farther than the first term, and it is safe to assume that all who graduate have received what will be of great value to them in life, even though they may never after make a drawing. They have received an impulse which will tend to develop in them such qualities as made the difference between the handling of the ships and guns of the Americans and the Spanish.

The school is conducted for the benefit of the students, but to receive

this benefit in its full extent, requires the full amount of effort on their part. As a rule they make this effort and receive the benefit, and I have yet to hear of a graduate who regretted the time and work spent here.

WM. H. THORNE, *Director.*

THE FOLLOWING STUDENTS ARE ENTITLED TO HONORABLE MENTION:

In the Senior Mechanical Class.

John Kleische, William W. Hodge,
Frank F. Schauer, Harry C. Brinton,
Paul E. Hottinger, Walter Arnaiz,
George F. Eisenhardt.

In the Intermediate Mechanical Class.

William Williams, Charles G. Shafer,
Otto Glein, Samuel Greenlee,
William Hall, Victor Johnson,
Philip Marratt.

In the Junior Mechanical Class.

Harry Collins, James B. Stevenson,
Thomas Yapp, Harry Gray.

In the Architectural Class.

Roy E. Blithe, Charles Ritzel,
William H. Gould, George Dewees,
George Fiselé.

In the Free Hand Class.

Robert F. Plum, Edwin McCausland.

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND, ENTITLING THEM TO TICKETS FOR THE NEXT TERM:

Harry Thompson, Herman H. Langefeld,
Frederick Schwartz, George J. Wolf,
Frank H. Stiffel, Alfred Whitney, Jr.

THE FOLLOWING STUDENTS, HAVING ATTENDED A FULL COURSE OF FOUR TERMS WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES:

William Bergman, Charles P. Richter,
Harry C. Brinton, Charles Ritzel,
Christian H. Clausen, Alexander Stevenson,
Emil P. Hottinger, Frank H. Stiffel,
John Kleische, Harry Thompson,
Edward V. McCaffrey, Lawrence Verga,
Owen F. Mullen, Alfred Whitney, Jr.,
John Wright Reeve, Jr., George J. Wolf,
Paul W. Zook;

and from the Branch School at Germantown Junction:

Walter L. Fitzgerald, Howard Beeson,
Elwood F. McLaughlin, Edward Gunderman,
William K. Harris.

ADDITIONS TO MEMBERSHIP.

JANUARY 1 to MARCH 31, 1899.

The following persons have been elected and qualified as members of the Franklin Institute during the three months beginning January 1st and ending March 31, 1899:

ABBOTT, A. V., Chief Engineer Chicago Telephone Co., 203 Washington street, Chicago, Ills.

ANDERSON, FRANK, Mining Engineer, 255 Second East street, Salt Lake City, Utah.

ARMITAGE, GEORGE T., Mechanical Engineer, 108 Girard Building, Philadelphia, Pa.

ARMSTRONG, E. J., Mechanical Engineer, care Ames Iron Works, Oswego, N. Y.

AYER, JAMES I., Manager, 5 Main street, Park, Malden, Mass.

BABCOCK, STEPHEN E., Chief Engineer Water Works, Little Falls, N. Y.

BACHMAN, F. E., Manager Buffalo Furnace Co., 62 Highland avenue, Buffalo, N. Y.

BAKER, CHARLES F., Superintendent Motive Power and Machinery, 439 Albany street, Boston, Mass.

BECK, Matthias A., Mechanical Engineer, 160 Clinton street, Milwaukee, Wis.

BEDELL, FREDERICK, Ph.D., Assistant Professor Physics, Cornell University, Ithaca, N. Y.

BELCHER, A. W., Superintendent Repair Shops, Cornell Steamboat Co., Rondout, N. Y.

BELLINGER, H. C., Metallurgist and Chemist, Northport, Wash.

BERDELL, THEODORE, Metallurgist, 100 Broadway, New York, N. Y.

BERLINER, E., Electrical Inventor, 1717 P street, Washington, D. C.

BIERWIRTH, L. C., Secretary New Jersey Iron Mining Co., Dover, N. J.

BIRD, WILLIAM W., President Broadway Foundry Co., Cambridgeport, Mass.

BLACKBURN, A. H., M. E., General Manager The Fuel Economizer Co., Matteawan, N. Y.

BLISS, WILLIAM L., Inventor of Bliss Electric Car Lighting System, 128 Front street, New York, N. Y.

BOILEAU, WILLARD E., Electrical and Mechanical Engineer, Columbus, Ga.

BREWSTER, FRANK H., Superintendent and Engineer Birmingham Iron Foundry, P. O. Box 418, Derby, Conn.

BRILL, GEORGE M., Managing Engineer of Swift & Co., 444 W. Sixty-fifth street, Chicago, Ill.

BRINLEY, CHARLES A., Manufacturer, 247 South Sixteenth street, Philadelphia, Pa.

BROOKS, MORGAN, Professor Electrical Engineering, University of Nebraska Lincoln, Neb.

BROWN, CHARLES SUMNER, Professor Mechanical Engineering, Vanderbilt University, Nashville, Tenn.

BUSH, HAROLD M., Mechanical Engineer, "The Dennison," Columbus, O.

BURKE, M. D., Civil Engineer, 404 Pike Building, Cincinnati, O.

CAKE, H. W., Assistant Superintendent of Stamp Mills, Calumet and Hecla Mining Co., Lake Linden, Mich.

CALVERT LOUIS L., Architect, 1604 Real Estate Building, Broad and Chestnut streets, Phila., Pa.

CAMBIER, JACOB, Chemist Colorado Fuel and Iron Co., Pueblo, Colo.

CANFIELD, FREDERICK A., Mining Engineer, Dover, N. J.

CAPP, JOHN A., Mechanical Engineer, 225 Union street, Schenectady, N. Y.

CHRISTIE, WM. WALLACE, Consulting Mechanical Engineer, Paterson, N. J.

CLEMENT, LEWIS M., Civil Engineer, 1013 Twelfth street, Oakland, Cal.

COFFIN, CHARLES E., Pig Iron Manufacturer, Muirkirk, Md.

COLWELL, JAMES M., Assistant Cashier, Kittanning, Pa.

COMLY, George N., Mechanical Engineer, Solvay Process Co., 1816 West Genesee street, Syracuse, N. Y.

CONRADSON, P. H., Chief of Bureau of Tests Galena Oil Co., Franklin, Pa.

COOK, EDGAR S., President Warwick Iron Co., Pottstown, Pa.

COOPER, HENRY R., Solvay Process Co., 1921 W. Genesee street, Syracuse, N. Y.

COX, J. D., JR., Manager Cleveland Twist Drill Co., Cleveland, O.

CROWELL, LUTHER C., Mechanical Engineer, 504 Grand street, New York, N. Y.

DAGGETT, H. M., JR., Electrical Engineer, care Welsbach Light Co., Gloucester, N. J.

DAVIS, F. HARLEY, Vice President Davis Calyx Drill Co., 203 W. One-Hundred-and-Seventeenth street, New York, N. Y.

DEANS, JOHN STIRLING, Civil Engineer, Phœnixville, Pa.

DODDS, E., Superintendent Chandler & Taylor Co., 2013 E. Tenth street, Indianapolis, Ind.

DONEY, DEWITT C., Chemist and Assayer, 1189 Fairfield avenue, Bridgeport, Conn.

EAVENSON, ALBAN, Chemist, 320 N. Twentieth street, Phila., Pa.

EMERICK, LEWIS W., Electrical Engineer, care Solvay Process Co., Syracuse, N. Y.

EWER, ROWLAND G., Mechanical Engineer, 119 Halsey street, Brooklyn, N. Y.

FINGAL, CHARLES A., Mechanical Engineer, Stewart avenue and Twenty-third street, Chicago, Ill.

FISH, CHARLES H., Agent Cochico Manufacturing Co., Dover, N. H.

FOSTER, EUGENE C., Instructor of Physics and Chemistry Temple College, Phila., Pa.

FRITZ, JOHN, Mechanical Engineer and Manufacturer, South Bethlehem, Pa.

FRYER, GEORGE G., Mechanical Engineer, Solvay Process Co., Syracuse, N. Y.

GILLIS, H. A., General Superintendent Locomotive Works, Richmond, Va.

GLEAVES, TAYLOR, Consulting Engineer, Lynchburg, Va.

GLENN, H. F., General Manager, Jackson & Woodin Manufacturing Co., Berwick, Columbia Co., Pa.

GOLDEN, M. J., Professor Practical Mechanics, Lafayette, Ind.

GOLDSBOROUGH, W. E., Professor Electrical Engineering Purdue University, Lafayette, Ind.

GOLDTHWAIT, ABEL G., Mechanical Engineer, 181 Eighth street, Troy, N. Y.

GREEN, GEORGE ROSS, Mechanical Engineer, 418 School Lane, Germantown, Pa.

GREEN, THOS. W., Superintendent Wilbraham-Baker Blower Co., 2518 Frankford avenue, Phila., Pa.

GUBELMAN, FRED J., Engineer, 792 Montgomery avenue, Jersey City, N. J.

HAND, HARRY W., Superintendent I. P. Morris Co., 1800 N. Sixteenth street, Phila., Pa.

HARKNESS, WILLIAM, Professor Mathematics U. S. Navy, U. S. Naval Observatory, Washington, D. C.

HARRIS, IRA, Marine Superintendent, U. S. A. T. Service, Army Building, New York, N. Y.

HAYNES, WM. L., Mechanical Engineer, 120 Durham street, Mt. Airy, Phila., Pa.

HENDERSON, J. C., Mechanical and Electrical Engineer, 11 Broadway, New York, N. Y.

HENNEY, J. B., General Manager Hartford Light and Power Co., 90 Vernon street, Hartford, Conn.

HEPBURN, FRANK, Extract Manufacturer, Jacksonville, Fla.

HERR, EDWIN M., Assistant General Manager Westinghouse Air-Brake Co., 271 Shady avenue, Pittsburg, Pa.

HERSCHEL, CLEMENS, Hydraulic Engineer, 2 Wall street, New York, N. Y.

HILL, GEORGE, Architect and Consulting Engineer, 44 Broadway, New York, N. Y.

HILLS, A. H., 23 California street, San Francisco, Cal.

HOE, ROBERT, Engineer and Manufacturer Printing Presses, 504 Grand street, New York, N. Y.

HOLLINGSWORTH, SUMNER, Engineer and Paper Manufacturer, 60 India street, Boston, Mass.

HOWARD, JOHN L., Manager Pacific Coast Co., Vernon Heights, Oakland, Cal.

HUMPHREY, JOHN, General Manager Humphrey Machine Co., 400 Main street, Keene, N. H.

HUMPHREY, RICHARD L., Chemist, Testing Laboratory Department of Public Works, City Hall, Phila., Pa.

HUNT, ALFRED E., Manufacturer and Civil Engineer, 4916 Wallingford street, Pittsburgh, Pa.

JACOBUS, D. S., Professor Experimental Mechanics Stevens Institute, Hoboken, N. J.

JEWELL, C. W., Mechanical Engineer, Beaufort, S. C.

JONES, FORREST R., Professor Machine Design University of Wisconsin, Madison, Wis.

JONES, W. CLYDE, Lawyer, 100 Washington street, Chicago, Ill.

JOST, J. F. W., Chemist, care Welsbach Light Co., Gloucester, N. J.

KELLER, E. E., Vice-President Westinghouse Machine Co., East Pittsburgh, Pa.

KIEFER, H. E., Analytical Chemist Lehigh University, South Bethlehem, Pa.

KUNZ, FRED. C., Bridge Engineer, Pencoyd Iron Works, Pencoyd, Pa.

LAMOTTE, ARTHUR, Chemist, Chester, Pa.

LEISEN, THEODORE A., Civil Engineer, Wilmington, Del.

LEONARD, ARTHUR G., Assistant to Superintendent of Motive Power and Rolling Stock N. Y. C. & H. R. R. R., Grand Central Depot, New York, N. Y.

LOBBEN, PEDER, Mechanical Engineer, 14 Leighton street, Fitchburg, Mass.

LOOMIS, F. J., Chief Engineer, 126 Chestnut avenue, Waterbury, Conn.

LORING, CHARLES H., Chief Engineer U. S. N., 239 Clermont avenue, Brooklyn, N. Y.

MACNUTT, BARRY, Electrical Engineer, Assistant Inspector of Ordnance U. S. A., 27 S. Linden street, South Bethlehem, Pa.

MAILLOUX, C. O., Electrical Engineer, 48 W. Seventy-third street, New York, N. Y.

MCKEE, JOSEPH J., Mechanical Engineer, Bethlehem, Pa.

MELLEN, EDWIN D., Soap Manufacturer, 1590 Massachusetts avenue, Cambridge, Mass.

MOORE, R. S., Superintendent Risdon Iron Works, Howard and Beall streets, San Francisco, Cal.

MULLER, E. A., Superintendent Springfield Machine Tool Co., 26 Miller street, Springfield, O.

MUMFORD, EDGAR H., Secretary and Treasurer The Taber Manufacturing Co., Plainfield, N. J.

MURRAY, T. J., M.D., Physician and Surgeon, Butte, Montana.

NEWCOMER, HARVEY, Instructor University of Pennsylvania, 4116 Spruce street, Phila., Pa.

NORRIS, R. V., Mining Engineer, 24 S. Franklin street, Wilkes-Barre, Pa.

O'NEILL, EMMET, Plumber and Gas Fitter, 4223 Frankford avenue, Phila., Pa.

O'NEILL, H. GIBSON, Electrical Engineer, and Electro-Therapist, 11 W. Thirty-ninth street, New York, N. Y.

OTTENS, HENRY H., Manufacturing Chemist, 123 S. Water street, Phila., Pa.

PAUL, JOHN WALLACE, Superintendent Pittsburgh Writing Machine Co., Kittanning, Pa.

PETTIT, JOHN READ, Student, Delta Phi House, South Bethlehem, Pa.

PHILLIPS, JOHN L., Salesman, 1921 Vine street, Phila., Pa.

PLATT, JOHN, Mechanical and Marine Engineer, 99 Cedar street, New York, N. Y.

RAND, ADDISON C., President Rand Drill Co., 400 West End avenue, New York, N. Y.

RICE, ISAAC L., President Electric Storage Battery Co., 20 Broadway, New York, N. Y.

RICHARDS, FRANCIS H., Mechanical Engineer and Patent Attorney, Hartford, Conn.

ROBINSON, SAMUEL ADAMS, M.D., West New Brighton, Staten Island, N. Y.

RODGERS, HOWARD S., Electrical Engineer, 420 W. Fourth street, Cincinnati, O.

ROWLAND, CHARLES BRADLEY, Civil and Mechanical Engineer, care Continental Iron Works, Brooklyn, N. Y.

SCHUMANN, GEORGE, Superintendent Scott Foundry Department Reading Iron Co., Reading, Pa.

SHANKLAND, E. C., Civil Engineer, 816 Rookery, Chicago, Ill.

SHAW, E. C., Mechanical Engineer, 104 Park street, Akron, O.

STANTON, F. McM., Agent of Copper Mines, Atlantic Mine, Houghton Co., Mich.

STANTON, J. R., Treasurer Copper Mining Co., 11–13 William street, New York, N. Y.

STEARNS, CHAS. K., Mechanical and Electrical Engineer, Room 808, 60 State street, Boston, Mass.

STEINMETZ, EDWARD G., Assistant Superintendent Electric Storage Battery Co., 1609 N. Fifteenth street, Phila., Pa.

STERN, WM. A., Electrical Engineer, 401 Drexel Building, Phila., Pa.

STEVENSON, A. A., Mechanical Engineer, Burnham, Pa.

STEWART, RALPH C., Student, 1031 Spruce street, Phila., Pa.

SYMONS, W. E., Superintendent Motive Power Plant System, Savannah, Ga.

TAYLOR, STEVENSON, Marine Engineer and Boiler Builder, Hoboken, N. J.

THOMPSON, EDWIN W., Mill Engineer, Charlotte, N. C.

TIGERSTEDT, A. F., Mining Engineer and Director Iron Works and Mines, Helsingfors, Finland.

WAITT, ARTHUR M., General Master Car Builder L. S. & M. S. Ry., Cleveland, O.

WALKER, JOHN, Mechanical Engineer, 635 Jackson Boulevard, Chicago, Ill.

WALLIS, PHILLIP, Master Mechanic, L. V. R. R. Co., Easton, Pa.

WEEKS, EDWIN R., General Manager Edison Light and Power Co., 1409 Cherry street, Kansas City, Mo.

WERNER, D. T., Ph.D., Chemist Liquefied Acetylene Supply Co., Lebanon, Pa.

WHEELER, F. MERRIAM, Secretary The George F. Blake Manufacturing Co., 91 Liberty street, New York, N. Y.

WHITE, HORACE M., Dentist, 1616 Chestnut street, Phila., Pa.

WHYTE, F. M., Mechanical Engineer Chicago & N. W. Ry. Co., 225 Dearborn street, Chicago, Ill.

WILD, CHARLES E. (Retired), Mulhouse, Alsace.

WILLIAMSON, R. B., Mechanical Engineer, Instructor Lehigh University, 440 Cherokee street, South Bethlehem, Pa.

WILLIS, WARREN E., Mechanical Engineer, 109 N. Twenty-second street, Phila., Pa.

WILSON, JAMES C., M.D., 1437 Walnut street, Phila., Pa.

WOLF, THEO. R., State Chemist of Delaware, Newark, Del.

WOLVERTON, B. C., Electrician Electrical Department N. Y. & Penna. Telephone and Telegraph Co., Elmira, N. Y.

YORK, H. W., Chief Engineer United Electric Light and Power Co., 108 Fulton street, New York., N. Y.

ZERR, G. B. M., Instructor Department of Science Chester High School, Chester, Pa.

ZIEGLER, S. LEWIS, Physician, 1509 Walnut street, Phila., Pa.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held April 5, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were considered:

Improvements in the Art of, and Apparatus for, Combustion.—Paul J. Schlicht, New York.

ABSTRACT.—The *Sub-Committee* made a preliminary report, setting forth that it had been found impracticable thus far to arrange for a suitable investigation of the merits of applicant's system and apparatus, under its own direct observation and command in the vicinity of Philadelphia, and suggesting a postponement of the investigation until such time as applicant should be able to comply with the sub-committee's requirements.

The report was adopted. [*Sub-Committee.*—Chas. James, Chairman; Thos. P. Conard, Spencer Fullerton.]

Engine Valve.—Alexander G. Hay, Philadelphia, Pa.

ABSTRACT.—The invention is the subject of letters-patent of the United States to Alexander G. Hay, No. 603,380, dated May 3, 1898.

The report is to the effect that applicant has proceeded on the assumption that the saving of room, in the case of a marine engine, was the most important feature to be considered. He has, therefore, conceived the idea of making the valve surround the cylinder, thus occupying a thin annular space. In so doing, however, the investigating committee believes that he has overlooked all the other essentials of a practical valve. The diameter of the valve becomes necessarily larger than that of the cylinder, and, therefore, becomes more cumbersome than existing forms. The keeping of the valve in alignment and avoiding binding, as well as packing the valve satisfactorily on convex and concave surfaces, are difficulties introduced by this construction, which, in the judgment of the examiners, are insurmountable. The statements of applicant in relation to losses due to clearance in existing engines, the examiners find to be erroneous. The report concludes that the invention has no practical value. [*Sub-Committee.*—Arthur Falkenau, Chairman; H. W. Spangler, L. F. Rondinella.]

Machine and Cutter for Generating Gear-Teeth.—E. R. Fellows, of Springfield, Vt.

ABSTRACT.—The Fellows gear shaper is a machine designed to generate a complete set of interchangeable gears from a single cutter, which is in form similar to one of the gears produced.

It consists essentially of a frame, or housing, adapted to carry the gear-blank and the cutter-slide in proper relation to each other, and connecting mechanism whereby the gear-blank and the cutter are caused to roll together on their pitch lines, while the latter reciprocates, like a shaping tool, and cuts away the material presented to it in the wheel blank.

For details of the operative features of the invention and its scope and limitations, reference is made to the report.

The invention is the subject of letters-patent of the United States to E. R. Fellows, No. 597,708, March 30, 1897, and No. 579,570, of even date.

The report concludes with the statement that the Fellows machine and cutter for generating gear-teeth mark a distinct advance in the art of gear cutting which should be recognized by the award of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—Wilfred Lewis, Tinius Olsen, Arthur M. Greene, Jr.]

Mr. Edward J. Moore presented a protest against the Committee's report in the case of his marine boiler.

The protest was referred to the sub-committee.

SECTIONS.

(*Abstract of Proceedings.*)

CHEMICAL SECTION.—The special meeting and *conversazione*, inaugurating the "Photographic and Microscopic Branch of the Chemical Section," took place on Tuesday evening, April 4th. The proceedings consisted of a brief address by Dr. Joseph W. Richards, President of the Section, setting forth the objects of the new branch, and an inaugural address by Dr. Charles F. Himes, of Carlisle, Pa.

The exhibits displayed were numerous, and of a highly interesting character; they comprised, among others:

A series of portraits, by Mr. F. Gutekunst, Philadelphia.

A fine display of microscopes, by Joseph Zentmayer, Philadelphia.

A collection of ruled glass screens for photo-engraving, by Max Levy, Philadelphia.

A collection of flash-light photographs, lantern slides and prints, by Mr. H. Parker Rolfe, Philadelphia.

Specimens of prints from films manufactured by Mr. John Carbutt, Wayne Junction, Philadelphia.

An exhibit of color-photographs, made by the "McDonough process," shown and described by Mr. H. F. J. Porter, Bethlehem, Pa.

Projections of color-photographs and a number of microscopic objects, by Mr. F. E. Ives, Philadelphia.

A photo-micrographic apparatus for studying the structure of models, etc., by Mr. Fred. D. Maisch, Philadelphia.

A collection of microscopic enlargements of insects, by Mr. John G. Baker, Philadelphia.

Photo-microscopic apparatus and miscellaneous apparatus, by Williams, Brown & Earle, Philadelphia.

Microscopes, photo-microscopic outfit and optical apparatus, by Messrs. Queen & Co., Philadelphia.

Microscopes and appurtenances and miscellaneous optical apparatus, by Lentz & Co., Philadelphia, representing the Bausch & Lomb Optical Company, Troy, N. Y.

A collection of photo-chromographs, by Photo-Chromotype Engraving Company, Philadelphia.

Selections from the collection of physical apparatus bequeathed to the Section by the late M. Carey Lea.

The meeting was largely attended, and proved to be a most auspicious opening for the new branch. All the exhibits were of a highly interesting and instructive character, and were thoroughly enjoyed.

The duty of conducting the affairs of the branch was confided to an Executive Committee composed of Mr. F. E. Ives, Mr. Theo. D. Rand, Dr. Henry Leffmann, Mr. W. N. Jennings and Mr. Thos. S. Stewart, Jr.

Following is an abstract of the address of Dr. Himes.

"This occasion does not mark a new departure for the Franklin Institute. It has always been alert and prompt to recognize advances in photography, to test and investigate them, and in all suitable cases to bring them before the larger public in its hall. This has been done through members as individuals interested in this subject, many of them eminent. This new branch simply proposes the fuller utilization of the activity of these members by concentration and organization.

"It means in no way or degree conflict, or competition with any of the long-established and effective photographic societies for which Philadelphia is distinguished. It would be a misfortune of it did so. It is intended rather to supplement them. Whilst they may cover the whole field of photography, there are some things—many things indeed—which they must necessarily regard as incidental. These, this branch will make its primary consideration. They are especially interested in the Art of Photography, and the pictorial and esthetic character of its results; this will concern itself rather with the Science of Photography and its increasing scientific and industrial applications. They desire results the most successful in every particular; this will enjoin failures, upon explanation of which higher success may be built. In short, these organizations are not on conflicting lines; not, indeed, on parallel lines, but rather on the same line—where one ends the other begins, the one continuing the work of the other. The Chairman, in his opening remarks, did not too decidedly emphasize Scientific Photography as the object of this branch. And yet there may be fields of activity for it outside of restricted scientific work. To briefly indicate a few, there are the educational possibilities and relations of photography, that may properly be considered. The Franklin Institute is a most effective educational institution. Again, the Institute, whilst it encourages and assists scientific activity, does much also by directing it into profitable and productive channels. There is to-day much photographic energy, especially of amateurs, running to waste, and largely for want of direction, or even suggestion. The production of Photographic Records might be made to absorb some of this. In England they seem to be fully awake upon this subject. There are many pictures in almost every locality that to-day have a limited topographical interest, that may acquire value with lapse of a few years. There are others that could be sought out with the certainty that they would acquire interest. This may be said to belong properly to historical associations. But they are not necessarily photographic, and suggestion could properly come from this body with such recommendations as to processes, sizes, mounting, storing, etc., as photographic experts could give. A picture of the old bridge at Columbia, about a year before it was burned, during the war, has acquired an interest not in

the thought of the speaker, when he took it, as a boy, by the old wet process, and long-forgotten, it was recognized in a magazine article, taken from a stray print.

"Photography in judicial procedure is another open field. Photography is in court, and it is there to stay. It is in under the rules of 'best evidence,' and the 'necessity of the case.' But its position is not well-defined. Whilst the evidence it affords is accurate, minute, complete and free from bias, the fact cannot but be recognized that it has limits of applicability and reliability. It can even lie and be made to lie. Questions of highest importance, and often of great novelty, and in increasing numbers will continually arise in regard to it. If this organization can contribute in any degree to its proper and creditable recognition by the courts, it may be of great service in the cause of justice. It might even become to a degree authoritative upon the scientific and technical aspects of such cases. In this connection a collection of reports of cases in which photography is employed in evidence in any way, suggests itself. With the arguments and decisions it might prove in a short time of great value, and might even entice the legal fraternity to the hall and library of the Institute.

"Without taking time to enumerate others, these will suffice to indicate something of the general character of the field of activity, beyond the strictly scientific, that seems to open up before this branch. It is a matter of congratulation that it has opened so auspiciously, and the effort of all should be to keep it at least fully abreast of all the advances of a rapidly expanding branch of science."

Stated Meeting, Tuesday, April 18th, Dr. Richards in the chair.

Dr. Harry F. Keller, Dr. Robert Bradbury and Prof. E. A. Partridge were appointed as a special committee to select and report to the Library Committee, from time to time, the titles of books and periodicals relating to physics and chemistry, to be purchased with the income of the M. Carey Lea Fund.

Prof. E. A. Partridge presented a paper on "Series in Spectra," giving a very comprehensive summary of the development of scientific opinion on the subject.

The thanks of the meeting were offered to the speaker, and the paper was referred for publication.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, April 12th, President, James Christie, in the chair.

Mr. Paul Kreuzpointner, Testing Department Pennsylvania Railroad, Altoona, Pa., read a paper entitled "Riddles Wrought in Iron and Steel," illustrated with several photo-micrographs of the same specimens of steel, which exhibited the differences in structure caused by differences in the heat treatment to which the test pieces was subjected. The paper was discussed by Messrs. Webster, Outerbridge and the author, and was referred for publication.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, April 13, Mr. James Christie, chairman *pro tem.*

The evening was devoted to the discussion of "Pumping Machinery; its Construction and Operation." The debate was opened by Mr. John Birkinbine, and was participated in by Messrs. J. J. De Kinder, John E. Codman and others.